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Development of a methodology for analysing and quantifying delay factors affecting construction projects in Libya

by

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ABSTRACT

Construction delays are one of the biggest issues facing the construction industry and affecting delivery in terms of time, budget and the required quality. The characteristics of delay factors and their level of impact vary from project to project, ranging from a few days to years. They have significant financial, environmental and social impacts in construction projects; therefore, it is vital to investigate the causes of delay and analyse their impact. In this context, the research study was initiated to develop a new methodology for analysing and quantifying the impacts of delay factors on construction projects.

A comprehensive literature survey was conducted to build up general background knowledge of delay factors in construction projects and particular attention was paid to identifying the potential differences in delay factors between Libya and the UK. A construction industry survey was conducted through a semi-structured questionnaire amongst contractors, consultants and owners. A total of 116 out of 300 responses (38.66%) were received from both countries. Statistical tests including T-test and Wilkinson rank test were executed to analyse the responses and present the findings from the survey. Following the findings from the literature review and an industry survey, a framework of Delay Analysis System (DAS) augmented with simulation model was developed by integrating the importance weight (IW) of each delay factor associated with critical activities using @risk tool.

The key function of the system is the flexibility to analyse and quantify the impact in project duration, considering the IW of each delay factor independently. The system was evaluated through two case studies from building projects in Libya using the developed system. The analysis of case study 1 using DAS found that the building project might be delayed by 97 to 103 days when considering the delay factors identified from Libya whereas the project might be delayed by 80 to 85 days when considering the delay factors identified from the UK. The evaluation results from the case study revealed that the impact of delay factors in Libya is higher than in the UK. This confirms that the impact of delay in construction projects is higher in developing countries than in developed ones and varies from project to project in the same country.

Finally, it is concluded that the system is a decision-supporting tool that helps to make government departments and decision-makers aware of the significance of delays in construction projects in terms of economic growth and the development processes. The key contribution of this study is the development of a strategy (delay analysis system) for analysing the impact of delay factors in the Libyan construction industry through better investigated, understood and documented reports. The system is expected to help policymakers, decision-makers and others stakeholders within the construction industry to gain a fuller understanding of the industry and to formulate short- and long-term construction strategies and policies that aim to improve the industry's processes and operations.

DEDICATION

To all my family

Who motivated and encouraged me at all times during the study

DECLARATION

No portion of this research referred to in this thesis has been submitted in support of an application for another degree or any other university. Other sources of information have been used by acknowledging them.

Signature: ……………………………………….

Date: …………………………………………….

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Thanks.

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List of abbreviation

Construction Industry	CI
Libyan Construction Industry	LCI
Program Evaluation and Review Technique	PERT
Probabilistic Network Evaluation Technique	PNET
Monte Carlo Simulation	MCS
Latin Hypercube Technique	LHT
General People's Committee (Council of Ministers)	GPC
Critical Path Method	CPM
Statistical Package for Social Science	SPSS
Contractor	C
Materials	MT
Equipment	EQ
Manpower	MP
Project Management	PM
Consultant	CNS
Owner	OWN
Early Planning and Design	EP&D
External Factors	EF

Category	Ctg
Importance Index	II
Importance Weight	IW
Average Weight	AW
Number of Respondents	R
Rank	RNK
Delay factor’s Number	DF No
Modulus of the number of causes in the delay category	M
Delay Analysis System	DAS
Frequency Index	FI
Severity Index	SI
Minimum Time	Min Time
Maximum Time	Max Time
Risk Factors	RF
Random Factors	RF
Visual Basic for Applications	VBA

Chapter 1-

Introduction

Chapter 1: Introduction

1.1 Introduction

This thesis deals with construction delays in the Libyan construction industry. Construction delay is a foremost problem facing the construction industry in almost all countries in the world. Delays occur in almost every construction project and their magnitudes vary considerably from project to project, ranging from a few days to years. It is generally understood that construction delay is the most critical factor affecting the delivery of construction projects in terms of time, budget and the required quality (Hancher and Rowings, 1981). However, it is very important to identify the exact causes and their significance in order to minimise and avoid the impact of delays in construction projects. Mansfield et al (1994) found that construction projects completed on time were a signal of project efficiency; however, construction processes depend on a number of unpredictable factors that occur from various sources. These sources include the performance of construction stakeholders, availability of resources, site conditions, contract types, weather conditions and the contractual relations between stakeholders. However, it rarely happens that a project is completed within the specified time and budget. In this context, this research study focuses on developing a methodology for analysing and quantifying the impact of delay factors in the Libyan construction industry. The study also presents comparative results about the impact of delay factors in the Libyan and the UK construction industries by conducting an industry survey and evaluating case studies of building projects.

This chapter presents an overview of the research study. It explores the rationale of the research by highlighting the main issues associated with construction delay and providing a method to reduce the impact of delays. This chapter also includes the research problem statement, research questions, aim and objectives of the research study, and an outline of the research methodology. The research methodology includes literature review, a construction industry survey, data collection and analysis, discussion of the results, a case study experiment and the development of a Delay Analysis System (DAS). Finally, this chapter highlights the contribution to knowledge, scope, and limitations of the research study, followed by an overview of the thesis structure.

1.2 Background of the study

The construction industry has unique characteristics in comparison to other industries. This means that every project is different, a situation which emanates from the project's own characteristics. For example, the project type, size, geographic location, and personnel involved emanate from the other subsystems within the industry, and also from those of the super-system. Hence, project execution is inherently risky and the lack of an appropriate approach to address these risks has led to a lot of undesirable results in project execution, particularly in the Libyan construction industry (Wells, 1986).

Traditionally, the failure to achieve project objectives including cost, time, quality and other targets is due to inefficiencies in the execution processes (Joseph, 2003). This, ultimately, causes client dissatisfaction. The following issues were identified, through the literature review, as affecting project performance in the construction industry.

1. Delays in the construction industry, either in developing countries or developed countries, are a serious problem, because they result in more members of staff being required, more hours to be worked, more equipment, more direct and indirect overheads, potential claims between owner and contractor, and more interest to be paid to financing institutions. In addition, rental or sale revenues will be lost for the duration of the delay and due to the uncertainty relating to the dates of completion. Disturbance of the order of the construction tasks and rushing through activities hastily is likely to jeopardise the quality of the project. The cost of the Millennium Dome project, for example, increased from an initial £339 million to £628 million, primarily due to changes of design and the impact of the weather (Zaneldin, 2006).

2. The ways to overcome or reduce delays and their associated negative effects are complicated (Zaneldin, 2006). This involves a number of aspects as follows:
    - Completion of Design: Provide enough time for the design team to produce clear and complete contract documents with no or minimum errors;
    - Quality Control: Establish efficient quality control techniques and mechanisms that can be used during the design process in order to minimise errors and mismatches;

- Procurement of materials and equipment: Develop advanced material procurement planning;
- Sub-contracting: Use specialist contracting provisions and practices that have been used successfully on past projects.

3. General knowledge and past research studies on delay analysis have resulted in the improvement of project management and completion rates. Previous studies revealed that the delay factors in the construction industry were change orders by the owner during construction; delays in progressing payments; ineffective planning and scheduling by the contractor; poor site management and poor supervision by the contractor; shortage of manpower; and difficulties in financing by the contractor. External factors also cause delays in construction projects, such as a lack of materials, equipment and tools on the market; poor weather conditions; and transportation delays (Asnsssshari et al, 2009).

4. Moreover, literature reviews identified that there are no standard methods or approaches suggested by researchers to reduce the effect of delay. However, delays in construction projects can be reduced through the joint efforts of participants in the construction industry. Clients, designers/consultants, contractors, suppliers, finance sources, educational institutions, manufacturers, and the government should cooperate to provide the necessary support for efficient management, and continuous work training programmes for personnel in the industry to update their knowledge and make them familiar with project management techniques and processes (Ogunlana et al, 1996).

5. Due to their construction engineering experience, developed countries have sophisticated methods such as advanced planning tools, supply chain management and advanced information communication to reduce delays (John, 2000). In this study, the UK has been selected as the benchmark for comparing the impact of delay factors between the UK and Libya, since the UK is a developed country and an appropriate location for collecting information related to current practices and their problems in the construction industry. These solutions can then potentially be transferred from one country to another.

6. There are no specific research studies in the area of delays analysis in Libya's construction industry. The author's belief is that there may be a set of unique factors in the Libyan construction industry, influencing construction project delays and the ways to address the associated problems.

Delays in completion of Libyan construction projects have significant financial and social impacts on all parties involved in the projects. According to a report published by the General People's Committee PGC (2003), 97% of construction projects associated with the public and private sectors between 1991 and 2003 suffered delays and had a high impact on project cost and time. During this period (which was Libya's blockade time) the price of construction materials (including steel) was very high and many projects were stopped in anticipation of a return to old price levels, causing direct delays. Contracting parties also created disputes between the contractor and owners, which further increased the projects' duration. In this context, this research study was initiated by the Libyan Government to develop a new methodology to reduce the impact of delays in Libyan construction projects.

1.3 Statement of the research problems

According to Moavenenzadeh (1987), the construction industry can play a significant role in economic growth and development processes if it is well understood. Thus, to enable the construction industry in Libya to fulfil its significant roles, it should be managed efficiently. This requires a better understanding of the Libyan construction industry and its associated characteristics, processes and delays factors.

The Libyan construction industry and its associated processes and operations appear to be restricted by many obstacles. Its current capacity and capability are unable to meet national construction demand. Consequently, hundreds of construction projects are suspended, delayed or stopped. Furthermore, high demand for construction projects is expected in future years. In addition, the Libyan construction industry has a poor image in the construction market due to its low performance over the past few decades (GPC, 2007).

Therefore, to improve the operations of the Libyan construction industry, it is necessary to understand what the key factors are affecting the construction industry and its associated operations; how the construction industry is organised; how construction activities are conducted; and what the major delay factors are in the Libyan construction industry. Thus, this study attempts to answer these questions.

1.4 Research questions

According to Yin (2003), research questions guide and determine the research strategy and methodology. Robertson et al (1996) define a robust research question as a foundation on which a research study is built. It helps to decide what sort of data is required, how to collect the best data, and the particular focus and analysis of the data. According to De Vaus (1990), the formulation of a research question is a process which involves interaction between the problem and data. The final research problem that evolves in this process reflects and makes sense of data.

In this study, the process of developing the research questions was based on a review of the literature related to the impact of delay in the construction industry during the course of this study. In addition, the questions were improved through discussion with construction industry specialists, and finally revised throughout all phases of the research process in order to meet the purposes of the study. At the end of this process, the study attempts to answer the following key questions:

1. What are the critical delay factors that are having an impact on Libyan and UK construction projects?

2. What are the effects of these delay factors on the construction projects concerned, and who is responsible for the delay factors?

3. What is the frequency and severity of the delay factors?

4. How can the influence of delay factors on Libyan construction projects be reduced?

1.5 Hypothesis

Based on the research questions identified in this study, the following hypothesis is set up:

1. *The impact of delay factors in construction projects in terms of time is higher in developing countries like Libya than in developed countries like the UK.*

2. *The development of a delay analysis system augmented with simulation model is expected to provide a decision supporting tool to analysing and reducing the impact of delays in Libyan construction projects.*

1.6 Aim and objectives of research study

The aim of the research study is to develop a delay analysis system for quantifying and reducing the impact of delay in Libyan construction projects. The system is part of strategy development for identifying and analysing the risks associated with delay factors in construction projects. This is expected to assist construction managers in identifying and managing the critical delay factors associated with construction project activities. To achieve this aim, the following objectives were set:

1. To review the literature to identify the list of possible delay factors associated with construction projects, and the existing techniques being used for analysing the delay factors;

2. To conduct a construction industry survey to identify the Importance Weight (IW) of each delay factor by ranking the delay factors associated with construction projects in both Libya and the UK;

3. To identify and rank the responsible parties (contractors, consultants and owners) in terms of impact level of delay in construction projects in both countries;

4. To develop a framework of a delay analysis system (augmented by a simulation model) to analyse and quantify the impact of delay factors affecting construction projects by integrating the critical delay factors and critical activities associated with the projects;

5. To run case studies from existing building projects to validate the proposed delay analysis system and provide recommendations for further development of the system.

1.7 Research methodology

This section discusses the research methodology chosen for the research study, which included both qualitative and quantitative approaches. The research methodology is defined as the systematic research methods or steps adopted to achieve the aim of a research project (Miles and Huberman, 1994). The key research methods adopted to achieve the objectives of the research study are the literature review; an industry survey with data collection and analysis; the development of a delay analysis system with a simulation model; and the evaluation of the model through case studies. The adopted methods in this study are discussed briefly below.

1. **Literature review:** A literature review was carried out to summarise the previous research findings in the area of delay factors that affect construction projects. The literature review has shown that the causes and effects of delays in the construction industry can vary from country to country due to the different environment and the techniques applied that can affect the construction process. The literature was also reviewed to identify the existing delay analysis techniques and tools with the aim of developing a strategy to reduce the impact of delay in the construction industry. The findings from the literature review were used to design the framework of the delay analysis system. This satisfied the first objective.

2. **Industry survey:** The industry survey was conducted to identify the importance weight (IW) of each delay factor and to rank the responsible parties in a construction project. The survey data was collected from large number of respondents through a

questionnaire, since this is the only feasible means to elicit a wide range of views or opinions from construction professionals and to allow statistical analysis of the results. Many statistical tests were used to analyse the survey data. Existing statistical tests as T- test and Wilcoxon rank test were performed to test the significance of the identified delay factors and responsible parties in both countries. The findings from the industry survey were used to design the framework of the delay analysis system. This satisfied the second and third objectives.

3. **Development of delay analysis system with simulation model:** Following the findings from the literature review and industry survey, a framework of a delay analysis system augmented by a simulation model was introduced to analyse and quantify the impact of delay factors that affect construction projects. This can be used as an initial warning system for analysing and quantifying the impact of potential delay factors in the construction projects by developing a new methodology integrated with the simulation model.

   The possible types and numbers of critical delay factors affecting each critical activity in a project were identified using site information and the knowledge of construction managers. The possible durations of each activity were calculated by integrating the influence values of delay factors affecting critical activities with random numbers generated by Monte Carlo simulation using @risk simulator. The system is expected to assist construction managers in identifying the potential delay factors and reducing the impact from the delays at the construction stage. This satisfied the fourth objective.

4. **Case study:** The introduced simulation model of a delay analysis system was evaluated by running case studies from building construction projects. The outcome of the case study results confirms that the proposed system is valid. This satisfies the fifth objective.

1.8 Research scope and limitations

As mentioned previously, the general purpose of this study is to explore and understand the delay factors in Libyan construction projects and its associated processes and operations. This also includes identifying the major delay factors and analyse their impact. However, the main scope of this study is to focus on the building construction projects of the public and private sectors in Libya.

Thus, the study is limited to building projects (public and private-sector) in different cities in Libya, considering geographical, technical and time constraints as well as the absence of relevant data relating to construction delay factors in other types of construction industries.

The study was narrowed within the following scopes:

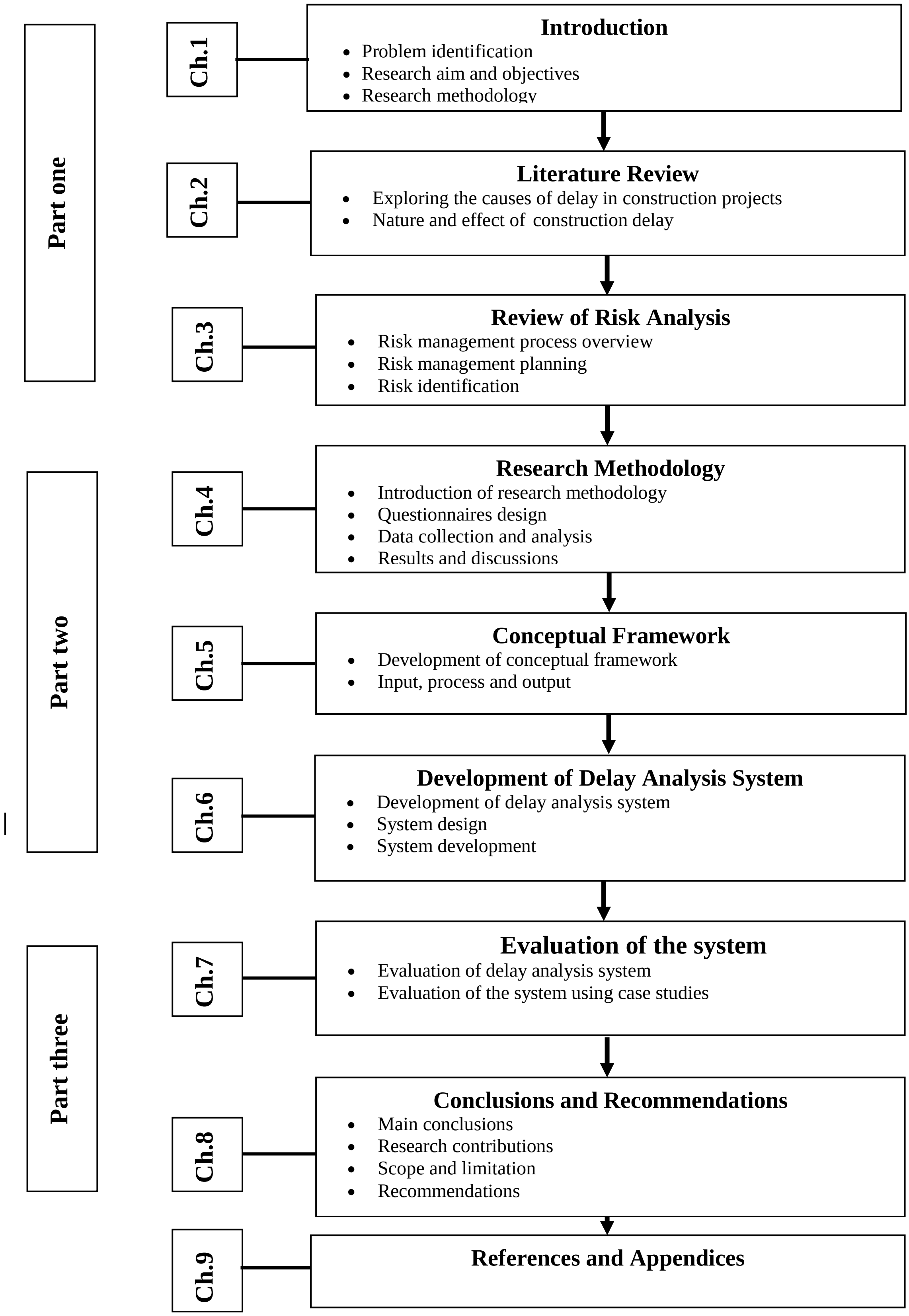
1. The study is focused on identifying the causes and effects of delay factors that influence the Libyan and the UK construction industries.
2. The respondents were selected only from contractors, owners and consultants from different locations within Libya and the UK.
3. The survey findings were used to design and develop the framework of a delay analysis system.
4. The critical activities and their associated delay factors were only used to analyse and quantify the possible delays in Libyan construction projects.
5. Influence factors found from the UK were used only to identify and compare the possible delay to a project using the case study of a Libyan building project.
6. The selection of delay factors affecting a critical activity were identified using the knowledge gained from construction professionals.
7. The knowledge from industry and the existing simulation program (@risk) were the main base upon which the delay analysis system (DAS) in the study was developed.

1.9 Thesis structure

The thesis comprises three main parts. The first part (Chapters 1-3) is focused on reviewing and exploring the delay factors in the construction industry and reviewing existing risk analysis and identification techniques which are being used to analyse delay factors.

The second part (Chapters 4-6) introduces the research methodology and processes, analyses the methodology for the empirical data, and discusses and interprets the study's findings. Part three (Chapter 7-8) includes the validation of the framework, conclusion and recommendation. Finally, references and appendices are included. Figure 1.1 provides a graphic representation of the thesis structure. A short summary of each chapter of the thesis is presented below.

Figure 1.1: The organisation of the study



Chapter 1: Introduction to the study

This chapter provides a general introduction to the research study. It includes brief discussion of the subject matter of the research by highlighting the main issues and explaining the background. The rationale and research questions of the study are presented. The chapter also includes the aim and objectives of the research study and briefly outlines the proposed research methodology. The chapter highlights the contribution, scope and limitations of the research. Finally, a thesis structure is presented, with a brief summary of each chapter.

Chapter 2: Literature review

A detailed description of previous literature related to the delay factors in construction projects from different countries is presented. The nature and effect of construction delays, including types of delay, are also discussed and presented.

Chapter 3: Review of risk analysis and management

This chapter provides a context for the research by presenting a detailed review of existing risk analysis and identification techniques which are being used to analyse delay factors, particularly in building construction projects.

Chapter 4: Industry survey and data analysis

This chapter provides justification for the primary research methodology chosen for this project. It discusses several methodologies, including the methods of data collection. The chapter also addresses questionnaire design, distribution, collection and data analysis, where the results of the survey and the review pointed to the need for further in-depth investigation into the major problems affecting the construction industry. Additionally, in this chapter, statistical testing is used to analyse statistical data, such as One-sample T-Test, Paired Samples T-Test and Wilcoxon rank test.

Chapter 5: Conceptual framework of delay analysis system

This chapter discusses a conceptual framework for identifying construction delay factors, considering information from industry reviews and the questionnaire survey to determine the possible delay in construction projects.

Chapter 6: Development of DAS augmented with simulation model

This chapter includes explanation and development processes of the delay analysis system. The system is developed using VBA programming language to rank and identify the potential risk of delay. The developed system is integrated with the conceptual framework discussed in Chapter 5.

Chapter 7: Evaluation of the DAS with case studies

This chapter includes a description of real case study projects. The examples are analysed, identifying problems that require resolution using the developed risk management process and tool. This chapter describes the evaluation of the functioning of the DAS using case studies of building projects. The system is expected to assist in identifying the possible durations of projects, taking into account the impact of associated delay factors

Chapter 8: **Conclusion, recommendations and further work**

This chapter includes conclusions and recommendations. The conclusions derived from the research study and recommendations for promoting good practice are presented in this chapter. Possible solutions for a delay minimisation strategy are suggested as part of the recommendations for further research.

Chapter 2-

Literature review

Chapter 2: Literature review

2.1 Introduction

This chapter presents the review of the literature related to the identification and analysis of the impact of delay factors from the contractors, owners and consultants' aspects in construction projects. The literature review includes the identification of state-of-the art methodologies regarding the identification and ranking of the critical delay factors in the construction industry. This chapter discusses the different types of delay factors which are responsible for delays in the delivery of a construction project. The existing literature related to the risk management process, including risk identification, quantitative risk analysis and the risk response planning, is discussed in Chapter 3. The delay factors related to contractors, owners and consultants are discussed and presented in this section.

2.2 Previous research studies in construction delay

Wael et al (2007) identified the major causes of delay in construction projects in Malaysia and the perceptions of the different parties regarding the causes and types of those delays. Their study decided on the causes and effects of delay in construction projects and found that delays are considered to be a serious problem in the construction industry for both owners and contractors. Wael et al's study included all factors causing delay in construction projects, considering three major categories: contractor, consultant, and owner. They concluded that the most important external factors causing the delay in construction projects were the lack of materials, and the unavailability of equipment and tools in the market. The next most important factors were poor weather conditions and delays in materials transportation.

Aibinu and Jagboro (2002) studied the effects of delays in project delivery in the Nigerian construction industry and investigated how the effects of delays on project delivery and the total construction cost of building projects can be minimised. A questionnaire survey for construction practitioners was used to investigate the effects of construction delays on project execution, and to minimise the effect of those delays.

Aibinu and Jagboro concluded that the delay could lead to both cost overrun and time overrun. The loss and expense claims arising from delay, and fluctuation claims due to project delay, had a significant effect on cost overrun. Loss and expense claims arising from ascertained and approved delay caused by the client or his agent also had a significant effect on cost overrun.

Sadi and Al-Hejji (2006) identified the causes of delays in construction in the Eastern Province of Saudi Arabia, and tested the importance of the causes of delay between each of two groups of parties. They also studied the differences in perceptions of the three major parties in involved, namely owners, contractors and consultants. They examined the delay in construction projects in Saudi Arabia and conducted a field survey that included twenty-three contractors, nineteen consultants and fifteen owners. Only one cause of delay was common between all parties, which were “change orders by the owner during construction”. Many causes were common between two parties, such as delays in progress payments, ineffective planning and scheduling by the contractor, poor site management and supervision by the contractor, a shortage of manpower, and difficulties in financing by the contractor. All parties agreed that the following causes were the least important: changes in government regulations; traffic control and restrictions at site; the effect of social and cultural factors; and accidents during construction.

Chan and Kumaraswamy (1994) identified the major causes of time overrun in Hong Kong construction projects. First they identified the principal causes of delays in both building and civil engineering projects in Hong Kong, and then investigated the relative importance weight of these causes. Secondly, they studied the differences in the perceptions of the three major industry participants – clients, consultants and contractors – to analyses the factors causing project delays. Finally, they tested the delay factor categories between two groups of respondents and compared the results with researchers’ results in other countries. Saudi Arabia and Nigeria were chosen for this research, in view of the similarity of the format of observations. They focused on identifying and ranking the order of importance weight. The main factors causing project delays were found to be ‘poor site management and supervision’, ‘unforeseen ground conditions’, and ‘low speed of decision-making involving all project teams’.

Odeh and Battaineh (2002) identified the major causes of delay in the Jordanian residential construction sector and assessed the relative importance of these causes from the points of view of consultant engineers, contractors and owners in residential projects. Delays in construction projects are common in the Jordanian construction industry, but can be avoided or reduced if the major causes of such delays can be identified and dealt with in a timely fashion.

The results of Odeh and Battaineh's study indicated that financial difficulties faced by contractors, change orders from the owner, and poor planning and scheduling of the project by the contractor were the major sources of delays in Jordan. It can be clearly argued that major delay causes are related to the internal environment of the system, especially that of the contractors, and to input factors relating to labour, while the external factors have very little effect on project delay.

Aibinu and Jagboro (2002) evaluated the delays and cost increases in the construction of private residential projects in Kuwait. They used a questionnaire survey to identify delay factors in the construction industry and to investigate the owner-experienced problems during the construction of private residences in Kuwait. They found three main causes of time delays: the number of change orders; financial constraints; and owners' lack of experience in construction. The other causes were contractor-related problems, material-related problems, and owners' financial constraints.

The amount of time delay also decreased with an increase in the pre-planning time period. Aibinu and Jagboro suggested that the owner therefore needed to invest more time and money during the design phase of a construction project to ensure a better quality and complete set of drawings, so that costly delays during the implementation phase of a project could be reduced.

AbdMajid and McCaffer (1998) identified the major causes of delays, effects of delays, and methods of minimising delays in construction projects in Aceh, Indonesia. A total of fifty-seven factors that caused delays were identified. These factors were grouped into eight groups of causes of delays: contractor-related delays; equipment-related delays; client-related delays; material-related delays; finance-related delays; consultant-related delays; external-related delays; and manpower-related delays. The result of analysis showed that time overrun and cost overrun were the two most common effects of delays in Aceh construction projects.

Alkass and Harris (1991) pointed out that delays are the most common and costly problem encountered in a construction project's life, and that analysing construction delays has become an integral part of the project. Even with today's technology, and management understanding of project management techniques, construction projects continue to suffer delays and project completion dates still get pushed back. They highlighted that there are several reasons that causes delay such as strikes, rework, poor organisation, material shortages, equipment failures, change orders, and acts of God. In addition to the above, delays are often interconnected, making the situation even more complex. Alkass and Harris examined and discussed the delay analysis techniques currently used by practitioners in the life of the construction industry, and also presented a new and effective delay analysis technique called the Isolated Delay Type (IDT). Delays on a construction site are inevitable and, as a result, many projects end up in litigation, making it a costly process. Present methods of analysing delays and preparing claims are inaccurate, time consuming and costly.

Frimpong et al (2004) identified and examined the causes of delay and cost overruns in the construction of groundwater projects in Ghana. A questionnaire was used to collect data from fifty-five owners, forty contractors and thirty consultants randomly. The results showed that there were several important factors underlying causes of delay and cost overruns in groundwater construction projects in developing countries such as Ghana. The five most important factors agreed by the owners, contractors and consultants were monthly payment difficulties from agencies; poor contractor management; material procurement; poor technical performances; and the escalation of material prices. Frimpong et al concluded that monthly payments difficulties were, according to the contractors and consultants' view, the most important delay and cost factor, while owners identified poor contractor management as the most important factor. Other factors that emerged as clearly less important, but still of interest, were bad weather and unexpected natural events.

Zaneldin (2006) investigated construction claims in the United Arab Emirates. The research looked at the types, causes and frequency of construction claims in the

Emirates of Dubai and Abu Dhabi using data collected from 124 claims related to different projects. The data were analysed to identify problem areas and to recommend how to reduce claims in future construction projects.

The following recommendations were made to prevent and deal with the claim:

- Allow reasonable time for the design team to produce clear and complete contract documents with no or minimum errors and discrepancies.
- Establish efficient quality control techniques and mechanisms that can be used during the design process to minimise errors, mismatches, and discrepancies in contact documents.
- Use special contracting provisions and practices that have been used successfully on past projects. Useful information can be found in the ASCE journal, which is about avoiding and resolving disputes during construction.
- Establish a strategy on how to deal with tighter scheduling requirements.

Ogunlana and Krit (1996) studied the causes and effect of delays in building construction projects in developing countries, using Thailand as an example of a developing economy. Data were collected via a postal survey from seventeen contractors, eighteen consultants and design firms, and one project client, who were also approached to get consent for site visit interviews. Eight contractors and six consultants gave approval, of which only twelve projects were selected for visits. Interviews were conducted on site using structured and unstructured interview schedules. A total of thirty persons, representing 2.5 persons per project, were interviewed.

Ogunlana and Krit concluded that the problems of the construction industry in developing economies can be nested in three layers: problems of shortages or inadequacies in industry infrastructure, mainly the supply of resources; problems caused by clients and consultants; and problems caused by the incompetence of contractors. The source and causes of delays were classified into six groups, such as owners, designers, construction managers, contractors, and resources suppliers.

According to Mohammed Al-Khalil (2000), delays in public utility projects in Saudi Arabia were directed towards three groups: owners of water and sewage projects; engineering consulting offices; and contractors working in water and sewage works. The sample selected for each of the three groups was as follows:

- Owners: water and sewage projects that were government owned.
- Consulting engineering offices: twenty engineering offices that were working in water and sewage projects in the Eastern and Riyadh provinces.
- Contractors: two hundred contractors classified as working in water and sewage construction according to the government classification system.

The result revealed several important underlying causes for the delays. The most important of these were cash flow and financial difficulties. These may be due to the contractor's inadequate capabilities or a delay by the owner in making progress payments. Another factor which may be important was to consider the government practice of assigning contracts to the lowest bidder without regards to qualification. In conclusion, the study investigated the contractors, consultants and owners (Water and Sewage Authority branch offices) to assess the frequency and extent of delay in water and sewage projects, and to identify the responsible party for the delay. It was found that a large number of projects experienced delays, especially those of a medium and large size. A time extension was requested by the contractor in all those delayed projects.

'Modernising Construction', a report published by the UK's National Audit Office and edited by John Bourn, exposed that 70% of the construction projects carried out by public departments and agencies were completed late. Moreover, recent research by the Building Cost Information Service (BCIS, UK) found that nearly 40% of all studied construction projects had overrun the contract period (Bourn, 2003).

According to Asnssshari et al (2009), the construction industry has a major role in the Iranian economy by generating employment and wealth. There is a huge demand in different sectors of the construction industry in Iran. In housing and residential sectors, there is a need for 800,000 additional units every year, while Iran's geographical position over the seismic belt necessitates the reinforcement and renovation of the country's old buildings. In the transportation sector, many projects, such as road, airport and railway buildings, are under construction. However, the process of construction in Iran is slow and expensive, and delay is one of the most recurring problems within Iranian construction projects. This, along with other issues such as increases in the price of land, materials and machines, and unavailability of resources, has led to a recession in the construction industry in Iran.

From literature review, it was found that several studies conducted in different countries to identify the delay factors. The table 2.1 presents the similarity and differences of delay factors identified by difference authors.

Table 2.1: Summary of delay factors in construction projects found by past studies in differences countries

Malaysia Wael et al (2007),	**Nigeria** Aibinu and Jagboro (2002)	**Thailand** (Ogunlana et al., 1996)	**Indonesia** Kaming et al., 1997)	**Saudi Arabia** Sadi and Al-Hejji (2006)	**Hong Kong** Chan and Kumaraswamy (1994)
1. Lack of materials 2. Unavailability of equipment and tools in the market 3. Poor weather conditions 4. Delays in materials transportation. 5. Design complexity 6. Plant procurement 7. Statutory undertakers	1. Contractors' difficulties in receiving interim payments from public agencies 2. Contractors' financial difficulties 3. Inadequate public agencies' budgets 4. Deficiencies in contractors' organizations 5. Deficiencies in planning and scheduling 6. Frequent variation/changed orders 7. Difficulties in obtaining construction materials 8. Deficiencies in public agencies' organizations 9. Contractors' unrealistic tenders	1. Materials procurement 2. Waiting for information 3. Poor contractor management 4. Labourers/tradesmen shortage 5. Waiting for information 6. Design delays 7. Planning and scheduling deficiencies 8. Construction plant shortages 9. Changed orders 10. Contractor's financial difficulties	1. Design changes 2. Poor labour Productivity 3. Inadequate planning 4. Locational restriction of the project 5. Skilled labour shortage 6. Equipment shortage 7. Materials shortage 8. Inaccurate prediction of equipment production rate 9. Inaccurate prediction of craftsmen production rate 10. Inaccuracy of materials estimate	1. Change orders by the owner during construction 2. Delays in progress payments 3. Ineffective planning and scheduling by the contractor 4. Poor site management and supervision by the contractor 5. Shortage of manpower 6. Difficulties in financing by the contractor 7. Changes in government regulations 8. Traffic control and restrictions at site 9. Effect of social and cultural factors 10. Accidents during construction	1. Poor site management 2. Unforeseen ground conditions 3. Delays in design information 4. Lack of communication between consultant and contractor 5. Inadequate contractor experience 6. Low speed of decision making involving all project teams 7. Client-oriented variations 8. Necessary variations of works 9. Delays in subcontractors' Work 10. Improper control over site resource allocation

Jordanian Odeh and Battaineh (2002)	**Kuwait** Aibinu and Jagboro (2002)	**Ghana** Frimpong et al (2004)	**United Arab Emirates** Zaneldin (2006)	**Iranian** Asnssshari et al (2009)	**UK** Zaneldin, (2006)
1. Financial difficulties faced by contractors 2. Change orders from the owner 3. Poor planning and scheduling of the project by the contractor. 4. External factors	1. Change orders 2. Financial constraints 3. Lack of experience in construction 4. Contractor and material problems	1. Payment difficulties from agencies 2. Poor contractor management 3. Material procurement 4. Poor technical performances 5. Bad weather and unexpected natural event	1. Contract ambiguity claims 2. Acceleration claims 3. Changes claims 4. Extra-work claims 5. Different site condition claims	1. Increase in price of land 2. Lack of materials and machines 3. Unavailability of resources	1. Change of design 2. Bad weather

Delays in material delivery, changes in design, poor planning, financial difficulties or delays in payment, lack of skilled manpower, variations in site conditions, fluctuations in resource prices and adverse weather conditions on site are the common delay factors found in the majority of countries (see Table 2.1). The previous research studies presented in Table 2.1 also found that different countries had similar construction delay factors. However, social and cultural factors, change orders by owners, delays in payment to main and sub-contractors, frequent changes to designs and specifications, and delays in approving design drawings were found to be key factors that delay projects in countries like the United Arab Emirates, Kuwait, Saudi Arabia, Indonesia, Jordan, Iran and Malaysia. Conversely, in the case of developed countries like the UK and Hong Kong, bad weather, design changes, variations in site conditions and poor site management were the major delay factors.

Moreover, past studies have highlighted that these delay factors have some relevance to other countries' construction industries, given that the causes of construction delays have been identified in a wide range of different countries, including Ghana, Hong Kong, Indonesia, Jordan, Iran, Saudi Arabia, Nigeria, Thailand, the United Arab Emirates, Kuwait, Malaysia and the UK. These studies are too numerous to describe in detail, but summaries of identified delays are available in past studies (Chan, 1998; Assaf and Al-Hejji, 2006; Sambasivan and Soon, 2007; and Lo et al, 2006). A comparison of the results of previous studies cannot give an entirely accurate result, since these studies used different techniques, measurements and methods of survey, and had different purposes. However, summative results of delay factors in different countries are valuable in providing an in-depth overview of possible construction delays.

From the above examples, it can be concluded that each study has identified significant delay factors, but that there are different sets of construction delay factors for different types of project. Previous literature has shown that the causes and effects of delays in construction industry can also vary from country to country, due to the different environments and the techniques applied that can affect the construction processes. Delay factors of construction projects in Libya will therefore be different, shaped by cultural, social and administrative factors.

2.3 Delay factors in construction projects

Delays in construction projects can be defined as the time difference between the date of project completion stated in the contract and the date of actual completion. Due to the fact that construction projects frequently suffer delays, the literature contains much discussion of this problem, as summarised above.

As stated, a large number of delay factors may lead to project delays in construction projects, arising from different parties and resources. These delay factors are countless, since each construction project has its own characteristics and environment. Efforts have therefore been made by many researchers to identify the most significant factors of delay in construction projects, which are discussed in the next section.

2.4 Identification of delay factors

The literature review was conducted through published books, conference proceedings, articles related to the research area and e- resources. In the next step, all the delay factors that may be encountered in a construction project were listed through a detailed review of the literature, and the possible delay factors recognised in practice were identified. These delay factors were grouped into four major categories as follows:

1. Contractor-related factors
2. Consultant-related factors
3. Owner-related factors
4. Others.

2.4.1 Delay factors related to contractor

Among all the construction parties, a contractor has the major responsibility to carry out most of the project activities. Similarly, if the project is not finished on time and within the allocated budget then the contractors is blamed. In reality, the contracting business is a challenging and demanding profession that contains many complex activities, and, to avoid project delays, the main contractor often holds full responsibility for the work of sub-contractors as well as his own. Basically, how the contractor deals with particular situations depends on the nature of the work and the type of contract (Shi and Arditi, 2001).

The capability of the contractor to finish the project according to the planned schedule mainly depends on two things: availability of resources (incorporating money, manpower, materials, and equipment and machinery) and managerial competence. There are two types of sources from which the contractor hires manpower: sub-contract and direct hire. If the sub-contractor causes delay to the construction project then both the owner and the main contractor have the responsibility to look for a solution to the problem. Therefore, it is essential for the contractor to constantly supervise the work performance of sub-contractors in order to maintain a balance between construction activities (Abdul-kadir and Price, 1995). On the basis of the literature review, nine contractor-related delay factors were identified in Table 2.2, but there are many other factors that may lead to project delays, and that can be broadly classified into four categories as follows:

Materials
Equipment
Manpower
Project management performance

Table 22: Factors of delay related to contractor

Groups	Factors
Contractor-related delays	1. Inadequate contractor experience 2. Inappropriate construction methods 3. Inaccurate time estimates 4. Inaccurate cost estimates 5. Poor site management and supervision 6. Improper project planning and scheduling 7. Incompetent project team 8. Unreliable subcontractor 9. Obsolete technology

2.4.1.1 Materials

Materials are one of the imperative components of any construction project and also the major expenditure for the owner. From the contractor's perspective, on-site management of materials is just one side of the picture. In reality, material procurement planning is vital for the contractor at the initial planning stages of the construction project (Abdulrahman and Alidrisyi, 1994). The failure to produce a proper procurement plan, or poor material handling by the contractor, may result in delays and many other problems such as the theft or deterioration of materials. According to Odeh and Bataineh (2002), the timely flow of materials is a vital responsibility of the contractor because in case of unavailability of materials additional expenditures will increase the cost of the construction project.

Koushki et al (2005) highlight another key aspect regarding material prices. According to them, an increase in material prices may sometimes hinder the owner's decision to acquire more materials, especially in the case of large building projects where rises in prices make a real difference. The decision to wait for a fall in material prices is crucial, because it may lead to delays in the whole construction project.

Similarly, modifications in the project specification sometimes occur due to errors in the design of the infrastructure. These design changes normally do not affect the types of materials used, but the acquisition of new materials may take a long time due to many factors such as price negotiations or waiting for client approvals (Wiguna and Scott, 2005). There are four materials-related delay factors, which have been identified in Table 2.3 below:

Table 2.3: Factors of delays related to material

Groups	Factors
Material related delays	1. Shortage of required materials 2. Delay in materials delivery 3. Changes in materials prices 4. Changes in materials specifications

2.4.1.2 Equipment

Construction equipment and machinery are used to perform repetitive tasks and operations. According to the function, the equipment used in the construction sector can be classified into two fundamental categories: operators and haulers (Abdulaziz and Michael, 1998). Operating equipment includes cranes and graders which can be left within the boundaries of the construction site, whereas haulers are dump, trucks, and other transportation equipment which is usually used to shift the materials to and from the construction site (Odeh and Bataineh, 2002). The equipment can either be hired or purchased by the contractors, depending on the frequency of their intended usage (Kwakye, 1997).

Some of the basic responsibilities of the contractor regarding the acquisition of equipment are selection of suitable equipment type, on-time delivery, proper maintenance, and prevention from damage.

The project may face slowdowns in the construction processes if the contractor fails to fulfil his responsibilities regarding equipment. AbdMajid and McCaffer (1998) opine that the selection of equipment by the contractor is very important for making an effective project plan, because a shortage or unavailability of equipment may badly disrupt the project schedule. Table 2.4 shows seven delay factors related to equipment.

Table 2.4: Factors of delays related to equipment

Groups	Factors
Equipment related delays	1. Insufficient numbers of equipment 2. Frequent equipment breakdown 3. Shortage of equipment parts 4. Improper equipment 5. Slow mobilisation of equipment 6. Equipment allocation problem 7. Inadequately modern

2.4.1.3 Manpower

Manpower or human resources is another most important aspect in carrying out construction operations and processes. Manpower includes foremen, inspectors, technicians, and civil/ mechanical and electrical engineers. Manpower can be classified into three categories on the basis of skill level: skilled, semi-skilled, and unskilled. The thoughtful selection and efficient management of manpower can be the key to the success of a construction project.

Hendrickson (1998) mentioned that "*productivity in construction is often broadly defined as output per labour hour*". In normal circumstances, the contractor is responsible for identifying and assigning project roles and responsibilities to the different professionals involved. Drewin (1998) observed that "*failure in selecting the correct number and category of the manpower force will severely affect the quality, the cost and the progress of the works and may result in complete failure of the project*."

In Libya, the majority of construction companies and contractors are local, but they import many foreigners with a construction industry background. In fact, this has also created some problems for contractors in the past, because importing or outsourcing manpower from foreign countries involves many complex processes such as selection, testing, health insurance, and travel and accommodation expenses (Ibrahim, 1987). These processes are often time-consuming and beyond the control of the contractor. In addition, due to the involvement of different nationalities, more issues may arise through cultural differences such as language barriers and different methods of working. These cultural differences may hinder the progress of the project. In order to avoid these problems, Odeh and Bataineh (2002) believe that interaction and coordination between the management and workers is very important in terms of understanding the work properly. There are seven manpower-related factors, highlighted in Table 2.5 as follows.

Table 2.5: Factors of delays related to labour

Groups	Factors
Manpower-related delays	1. Slow mobilisation of labour 2. Shortage of skilled labour 3. Manpower productivity 4. Manpower supply 5. Absenteeism 6. Strikes 7. Low motivation and morale

2.4.1.4 Project management performance

The project management environment is not stable and changes every day. According to Kraiem and Dieknam (1987), this environment is becoming more complex with the new developments in the project management context. Before looking at project management performance, it is better to first understand the exact meanings of project management. The Project Management Institute (1996) defined project management as "*the application of knowledge, skills, tools, and techniques to project activities in order to meet or exceed stakeholder needs and expectations from a project*". In addition, the successful application of project management requires many other skills such as project planning, teamwork, and ensuring error-free delivery. However, the contractor usually faces few barriers in implementing successful project management.

During the construction project, a contractor performs various duties that contribute to project management performance. These duties and responsibilities normally include planning and scheduling, interaction and coordination with other construction participants, and monitoring and controlling purveyors and sub-contractors (Assaf and Al Hazmi, 1995). In order to ensure effective project monitoring and control, a contractor must implement a proper communication plan by involving all the construction stakeholders; this normally includes suppliers, sub-contractors, the client, management, and local authorities. Horner and Duff (2001) suggested that meeting from time to time can create an effective environment for the construction participants to deal with any construction problems, such as delays.

Project quality control is another issue that can have an adverse impact on the construction project. If insufficient care is taken to achieve the required quality standard, then it may lead to particular activities or the entire project being repeated (Carnell, 2000). Therefore, the contractor should bear in mind that each project activity has its own specific requirements, and that selecting an appropriate workforce for completing the task may also help to achieve the desired quality control. In addition, proper training and motivation on site can also increase the productivity of the workforce. On the other hand, adopting inadequate methods of selection and training with no motivation may lead to meagre productivity, which in turn causes delays to the entire project. Table 2.6 displays fifteen delay factors associated with project management performance.

Table 2.6: Factors of delay related to project management

Groups	Factors
Project Management	1. Lack of motivation among contractor's members 2. Shortage of contractor's administrative personnel 3. Shortage of technical professionals in the contractor's organisation 4. Poor communication by the contractor with the parties involved in the project 5. Contractor's poor coordination with the parties involved in the project 6. Slow preparation of changed orders requested by the contractor 7. Ineffective contractor head-office involvement in the project 8. Poor controlling of subcontractors by contractor 9. Loose safety rules and regulations within the contractor's organisation 10. Poor qualifications of the contractor's technical staff assigned to the project 11. Improper technical studies by the contractor during the bidding stage 12. Ineffective planning and scheduling of the project by the contractor 13. Ineffective control of project progress by the contractor 14. Inefficient quality control by the contractor 15. Delay in the preparation of contractor submissions

2.4.2 Consultant-related delay factors

The client may consult with other professionals who can assist him in organising the entire construction project. These professionals are called consultants. The main duties and responsibilities of a consultant may be to design the infrastructure of the project, which includes architectural, mechanical, structural, and electrical designs. Some other responsibilities may include the preparation of project related documents such as bills, drawings, specifications, and tender documents (Long et al, 2004). Furthermore, in some cases, consultants also conduct project planning, cost control and estimation, and quality control.

In normal circumstances, consultant-related delays occur during preparation of drawings, during the adoption of design drawings, while taking design approvals from contractors and client, and when performing inspection procedures. There are many possible reasons behind these types of delays; prominent factors include inexperienced consultancy staff, poor qualifications, inadequate communication and coordination skills, and improper planning (Gunlana and Krit, 1996). Odeh and Battaineh (2002) believe that during the construction processes, the enquiries and inspections of the consultant may slow down the progress of the work. In response, the contractor may come up with solutions to the problems; however, these solutions may not satisfy the consultant, and could result in the work having to be redone. Effective control and command over production on the construction site is a major element that contributes to the success of implementing the project; conversely, hindrances in performing these activities can have severe impacts on a construction project. Table 2.7 shows the nine consultant-related factors that can result in construction delays.

Table 2.7: Factors of delay related to consultant

Groups	Factors
Consultant-related delays	1. Poor qualification of consultant engineer’s staff assigned to the project 2. Delay in the preparation of drawings 3. Delay in the approval of contractor submissions by the consultant 4. Poor communication between the consultant engineer and other parties involved 5. Poor planning and coordination by the consultant engineer with other parties involved 6. Delays in performing inspection and testing by the consultant engineer 7. Slow response from the consultant engineer to contractor inquiries 8. Inadequate design specifications 9. Poor contract management

2.4.2 Owner-related delay factors

The owner or client is the key participant during the entire construction process. Kwakye (1998) mentioned that the owner’s duties and responsibilities are onerous, and that he or she needs other knowledgeable parties to manage or organise the construction project. In a few cases, owners have in-house project management teams that participate in the construction process, but most of the time, owners hire a project manager and external parties to handle the project (Odeh and Battaineh, 2002).

One of the most crucial decisions that owners need to take at the beginning of the project is to determine the duration of the contract. Many owners prefer fast completion of work but thorough investigations should be conducted to decide the contract duration. Another major factor that delays the initialisation of the project is the owner’s failure to hand over the site to the contractor. Therefore, the personal involvement and quick decision-making on various matters by the owner in the initial phases of the project may accelerate the project’s progress. Kimmons and Loweree (1989) observed that “*the working relationship between an owner and a contractor is one of the most crucial determinants of project success and this relationship also develops trust between the two parties”*. The owner must participate in the construction project horizontally and vertically, but without interrupting the contractor's project plan. In addition, financial matters should also be taken into account, and the owner must ensure the on-time availability of funds; lack of financial stability may cause many problems, such as extensive delays due to labour strikes or material mismanagement (Chan and Kumaraswamy, 1997).

Based on the literature review of owner-related delay factors, thirteen factors have been identified, and are shown in Table 2.8.

Table 2.8: Factors of delays related to owner

Groups	Factors
Delays related to owner	1. Delay in furnishing and delivering the site to the contractor 2. Unrealistic contract duration 3. Delay in the settlement of contractor claims by the owner 4. Suspension of work by the owner's organisation 5. Delay in issuing of change orders by the owner 6. Slow decision-making by the owner's organisation 7. Interference by the owner in the construction operations 8. Uncooperative owner with the contractor complicating contract administration 9. Delay in progress payments by the owner 10. Owner's poor communication with the construction parties and government authorities 11. Owner's failure to coordinate with government authorities during planning 12. Poor coordination by the owner with the various parties during construction 13. Excessive bureaucracy in the owner's administration

2.4.4 Other factors

There are two other critical factors which can cause delay to a construction project: early planning and design, and external factors.

2.4.4.1 Early planning and design

The early planning and design stage may positively or adversely affect the life cycle of the entire project. Accurate, precise, and adequate planning can result in smooth progress of construction activities and ultimately accomplish the work on time, but it requires a great deal of attention, and extensive information about the project and interrelated matters. As Carnell (2000) wrote, "*the purpose of the provision of information and the use of the various planning tools is to enable the parties to put their respective contract obligation into effect. It can be reduced to a single question: how are to going to deliver this project on time and within budget?"* He further opined that incomplete and unclear documents, design, and specifications may create an unpleasant environment on site that can create problems for the owner and other construction participants.

It is important to recognise the crucial role of drawings in the early design phases, and, for this purpose, a proper communication or coordination plan has great significance. Odeh and Battaineh (2002) highlight the information which is necessary for the drawings, including the size, location, shape, infrastructure, and materials related to the design of the project.

On the basis of previous literature, four delay factors can be identified related to early planning and design, and are shown in Table 2.9.

Table 2.9: Factors of delays related to early planning and design

Groups	Factors
Early planning and design	1. Changes in the scope of the project 2. Ambiguities, mistakes and inconsistencies in specifications and drawings 3. Subsurface site conditions materially differing from contract documents 4. Original contract duration is too short

2.4.4.2 External factors

Some factors are outside the control of construction participants. For instance, the weather conditions in Libya in the summer are very hot, and the temperature normally exceeds 40 degrees Celsius. On the other hand, the weather conditions in the United Kingdom are worst in the winter season, when the temperature can typically fall to -5 or -8. In such intense conditions, contractors may face many difficulties that normally result in either slowdown of the construction process or, sometimes, a complete stoppage of works. These difficulties may include disruption to utility lines such as gas, electricity or water. Ogunlana and Krit (1996) mentioned that social and cultural festivals and celebrations may also affect the time it takes labour to reach the job site, negatively affecting the productivity of the construction project and potentially resulting in minor delays.

As discussed earlier, increases in the prices of raw materials can also have a significant impact on a construction project, yet is a factor also beyond the control of the owner and contractor. This is evidenced by the recent case in Libya, when many projects were stopped due to the prices of steel doubling in 2011. These external factors may also create clashes or disputes between the construction participants, which will further increase the product cost and duration (Odeh and Battaineh, 2002). Eight external-related factors are included in Table 2.10.

Table 2.10: Factors of delays related to external factors

Groups	Factors
External-related delays	1. Unforeseen ground conditions 2. Unexpected geological conditions 3. Problems with neighbours 4. Unusually severe weather 5. Conflict, war, and public enemy 6. Poor weather conditions on the job site 7. Traffic control and restrictions on the job site 8. Rises in the price of materials

2.5 Nature and effect of construction delay

This section aims to present a general overview of construction delay, including the types of delay found by researchers. Construction delays can be categorised according to the liability of the construction parties, the occurrence of delay, and the effects of delay. This section identifies and explains these types of construction delay and gives examples of each.

2.5.1 Type of delay

According to Pickavance (2005), the technical meaning of the term “delay” in construction projects has not been defined correctly since it has a different sense to different conditions during the project execution. However, the term is normally used as an extended the duration or delay in the start or finish date of any a project activities. Delays therefore cause the time extension and variation in cost allocation the impact in time and cost will only occur when the delay lies on the critical path of the programme.

Braimah (2008) stated that delayed completion of any projects is generally caused by the actions or inactions of the project parties including the contractors, consultants, owners, or others (e.g. acts of God). Based on these sources and the contractual risk allocation for delay-causing events, Braimah has classified delays in to four categories as follows

- Critical and non-critical
- Excusable and non-excusable.

In the process of determining the effect of a delay on construction project, it is necessary to determine whether the delay is critical or noncritical. It is also required to fine the delays are concurrent or non-excusable. However, delays can also be further classify into compensable or non-compensable delays (Trauner and Theodore, 2009)

2.5.2 Critical and non-critical delays

Delays that result in extended project completion times are known as critical delays, (Callahan et al, 1992). In the case of excusable critical delays, the contractor will generally be entitled to a time extension. Changing the type of structural steel members while the contractor is erecting structural steel is a clear example of a critical delay that is likely to delay the contractor's overall completion of the project. However, many delays occur that do not delay the project completion date or milestone date.

The concept of critical delays emanates from critical path method scheduling, and all projects, regardless of the type of schedule, have critical activities. If these activities are delayed, the project completion date or a milestone date will be delayed. In some contracts, the term controlling item of work will be used. Normally, this refers to critical activities or critical paths that if delayed will delay the completion date (Trauner and Theodore, 2009). Determining which activities truly control the project completion date depends on the following:

- The project itself;
- The contractor's plan and schedule;
- The requirement of the contract for sequence and phasing;
- The physical constraints of the project.

Non-critical delays are delays incurred off the critical path which do not delay ultimate project performance. If the delay in this case is excusable, the contractor does not have the right to receive a time extension, because this type of delay does not have an effect on the overall completion of the project (Leary and Bramble, 1988). However, noncritical delays may affect the contractor's cost performance; in this case, the contractor may have the right to receive additional performance costs.

2.5.3 Excusable and non-excusable delay

2.5.3.1 Excusable

All delays are either excusable or non-excusable. An excusable delay, in general, is a delay that is due to an unforeseeable event beyond the contractor’s or the subcontractor’s control. Normally, based on common general provisions in public agency specifications, delays resulting from the following events would be considered excusable:

- General labour strikes
- Fires
- Floods
- Acts of God
- Owner-direct changes
- Errors and omissions in the plans and specifications
- Differing site conditions or concealed conditions
- Unusually severe weather
- Intervention by outside agencies
- Lack of action by government bodies, such as building inspection.

These conditions may be reasonable, unforeseeable and not within the contractor’s control (Trauner and Theodore, 2009), and the analyst will conclude that a delay is excusable based solely on the preceding definition. Decisions concerning delay must be made within the context of the specific contract. The contract should clearly define the factors that are considered valid delays to the project and that justify time extensions to the contract completion date (Trauner and Theodore, 2009). For example, some contracts may not allow for any time extensions caused by weather conditions, regardless of how unusual, unexpected, or severe.

2.5.3.2 Non-excusable delay

Non-excusable delays are events that are within the contractor’s control or that are foreseeable. These are some examples of non-excusable delays:

- Late performance of subcontractors;
- Untimely performance by suppliers;
- Faulty workmanship by the contractor or subcontractors;
- Labour strike.

Again, the contract is the controlling document that determines if a delay would be considered non-excusable. For example, some contracts consider supplier delays excusable if the contractor can prove that the materials were requisitioned or ordered in a timely manner, but that the material could not be delivered due to circumstances beyond the control of the contractor. Other contracts may not allow such delays. The owner and the designer or drafter of the contract specifications must be sure that the contract documents are clear and unambiguous. Similarly, before signing the contract, the contractor should fully understand what the contract defines as excusable and non-excusable delays (Trauner and Theodore, 2009).

2.6 Chapter summary

To identify the causes of construction delays, a detailed literature review was carried out using international journals, conferences, and books. Previous literature has shown that causes and effects of delays in the construction industry can vary from country to country, due to different environments and the techniques applied that can affect the construction processes.

The review of literature found few research studies related to the analysis of delay factors in the Libyan construction industry. However, it was also found that no studies to date have ranked the delay factors affecting the Libyan construction industry. In addition, there were few studies carried out in relation to delay analysis systems, which aim to minimise the effects of delay in the construction industry.

A total of seventy-five delay factors were listed from the literature review, and these were sub-divided into eight different groups. These delay factors were considered during the design of a questionnaire that aimed to rank the delay factors using the responses collected from construction industry representatives, including consultants, contractors and owners. The possible delay factors in construction projects are also categorised into internal and external delay factors as follow:

1. **The key internal delay factors are:** change orders by the owner during construction; delay in progressing payments; ineffective planning and scheduling by the contractor; poor site management by the contractor; a shortage of labour; and difficulties in financing the project by the contractor.

2. **The key external delay factors include:** lack of materials and equipment; unavailability of required tools on the local market; and adverse weather conditions. However, the involvement of government, particularly in a developing country, where contracts are awarded to the lowest bidders without analysing the technical capability of contractors, is one of the main external factors delaying a project. Malaysia, Nigeria and Saudi Arabia have all reported this type of problem as an external factor.

Finally, the review of literature found that there are few research studies related to delay analysis methods in the construction industry. Furthermore, there are no research studies that have developed a framework of a delay analysis system to minimise the effect of delay factors in the construction industry. Equally, there are no reports identified in this review on the ranking order of delay factors in the Libyan construction industry.

The next chapter will explore project risk management processes.

Chapter 3-

Review of Risk Analysis and Management

Chapter 3: Review of Risk Analysis and Management

3.1 Introduction

This chapter provides a detailed review of existing techniques of risk analysis and management in construction projects.

The chapter presents a flow diagram of key stages/phases of risk analysis and the management process. The details of a risk management plan are then explained, since delay is considered a major risk in a construction project. The risk management plan includes risk identification, qualitative and quantitative risk analysis, risk response planning, and risk monitoring and controlling. The research study mainly focuses on the quantitative risk analysis approach for analysing the risks associated with building construction projects. The next section starts with the overview of the risk management process.

3.2 Risk management process

The analysis and management of risks related to a project is an important part of the decision-making process. According to Hossen and Hicks (2000), Project Risk Management (PRM) is defined as a process of taking management actions with the aim of maximising the chance of achieving project objectives and considering all identified risks available in a project. Monitoring risk exposure and adjusting project strategy are key approaches to keeping the risks within an acceptable level and achieving the assigned project objectives.

Patterson and Neailey (2002) defined the risk management methodology as a cycle process that consists of five stages. These are initiated at the risk identification stage followed by assessment, analysis, reduction and/or mitigation, and monitoring. The Project Management Institute (2004) suggests six phases as part of a risk management process: risk management planning; risk identification; qualitative risk analysis; quantitative risk analysis; risk response planning; and risk monitoring and control.
Furthermore, Kleim and Ludin (1998) highlighted four phases of the risk management

process, which include identification, analysis, control, and reporting of possible risks. However, Chapman and Ward (1997) suggested a project risk management process of nine phases:

1. Definition of the main aspects of the project;
2. Focusing on a planned approach to risk management;
3. Identification of the source that causes risks to arise;
4. Proving the information about the assumptions and relationships of risk;
5. Assigning the ownership of risks and responses:
6. Estimating the level of the uncertainty;
7. Evaluating the relative impact of the various risks;
8. Planning the possible responses; and
9. Managing the project risks by monitoring and controlling at execution stage.

Chapman (2001) and Elkington and Smallman (2002) suggested that the PRM process consists mainly of two phases, as follows:

1. Risk analysis, which includes the identification, prioritisation, estimation and evaluation of risk; and
2. Risk management, which includes planning appropriate responses, and monitoring and managing those responses.

Although previous authors have suggested different phases of the risk management process, the author believes that the following are the key stages/processes that should be followed throughout the risk management process. These stages, which are widely applicable in the risk management process (Hartman and Ashrafi, 2002) are:

- Planning of risk management;
- Identifying the risk;
- Analysing the risk qualitatively and quantitatively;
- Planning the risk response;
- Monitoring and controlling the risks.

The present study considered all aspect of the risk management process but mainly focuses on the quantitative analysis of the risk management process using Monte

Carlo simulation techniques to generate random numbers. In this study, project delay is considered a key risk factor in a construction project. The next section discusses the details of the risk management process, following the phases set out above.

3.3 Risk management planning

This section explains about a risk plan that needs to be established for the management of any possible risks that may occur in a project. In this stage, a team is assigned to identify a reliable risk management plan that helps to establish the possible activities of risk management of a project. Normally, a flow diagram is prepared, outlining brief actions or steps that should be taken throughout the risk management process (see Figure 3.1).

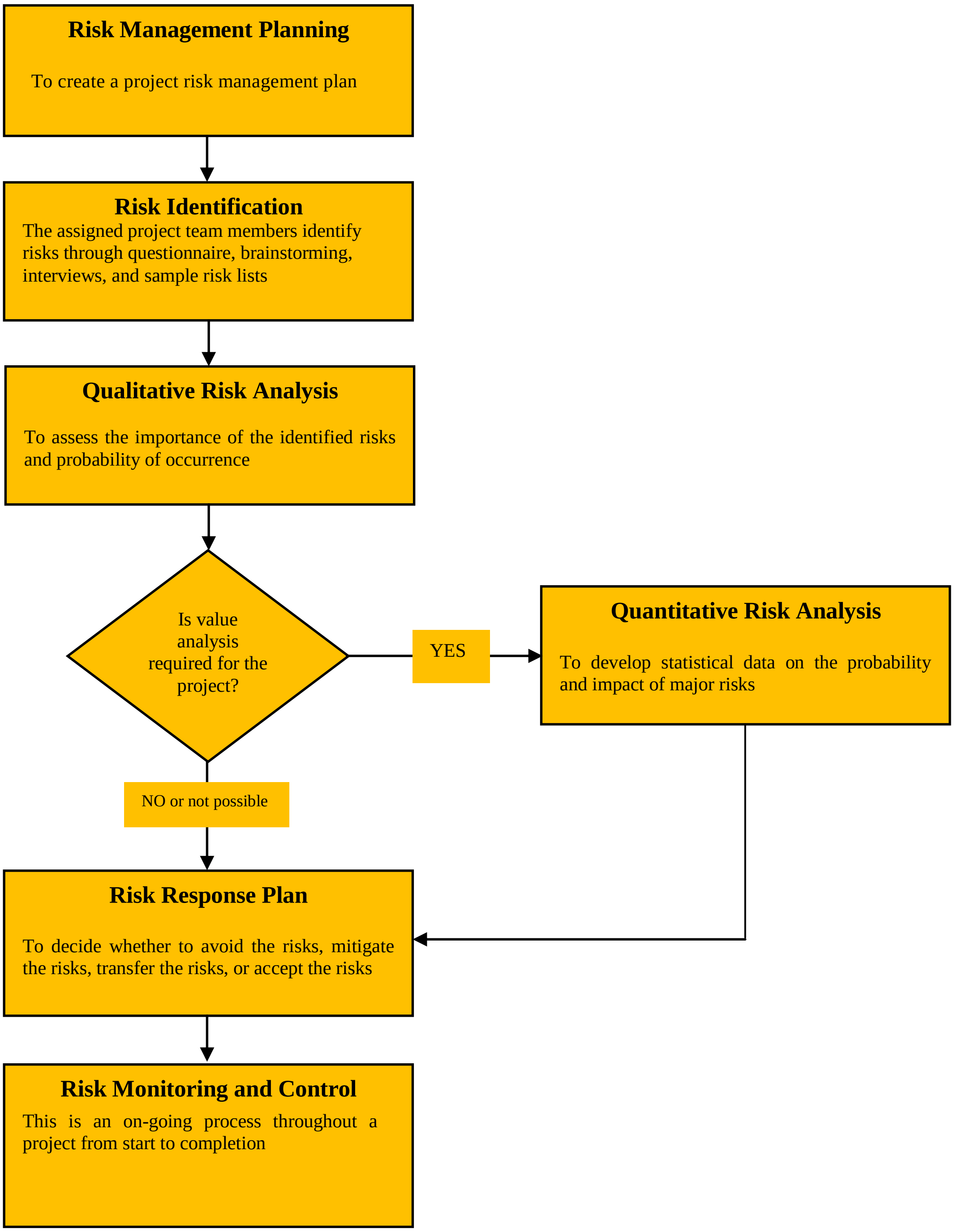


Figure 3.1: Flow diagram of risk management process (Thomas et al, 2004)

The next section discusses risk identification, which is considered the first step in the risk management process.

3.4 Risk identification

The systematic process of planning, identifying, analysing, responding to, and monitoring project risks is known as risk management. The risk identification stage focuses on finding out and identifying all possible risk factors that can affect the project activities. Many studies consider that risk identification is the most important element of the risk management process, since no further analysis and mitigation can be done without identifying the possible risks in a project. Risk identification is both an important and a difficult task, meaning that the process requires ‘some creativity and imagination’ (Chapman, 2001). The identification process can be made more efficient by employing the skills and experience of experts, as well as a large number of tools and techniques that are being used in the risk identification process. These techniques are checklists, interviews with individuals or groups, brainstorming, or using the Delphi technique (Morano, 2006).

3.4.1 Checklists

Risk identification checklists are prepared using historical information, previous experience on projects of a similar nature, and other sources of related information. In practice, this is revised at the time of each project’s completion, with the aim of improving the checklist for future projects (Morano, 2006). In the present study, existing literature and recent publications were used to prepare a list of delay factors (risks) in building construction projects, providing a foundation for the study’s analysis of the impact of those risks.

3.4.2 Interviews

This technique is an interactive dialogue that helps to elicit risks directly from the interviewee. In this technique, individuals with expertise in a relevant area of risk are interviewed to assess risk factors, discover possible improvements, measure possibility, and draw out data. In the current study, this technique was used to confirm the developed list of the possible delay factors (risks) in construction projects, using the aforementioned checklist (Morano, 2006).

3.4.3 Questionnaires

A questionnaire is a widely accepted method of data collection, particularly for descriptive purposes, within a research study (Robson, 2002). A questionnaire contains a number of questions for the respondent to answer, and can be distributed either personally, by email, or by post (Morano, 2006). There are three types of questionnaire:

1. Open questionnaire: by giving the respondent questions to answer freely.
2. Closed questionnaire: by asking the respondent to select the answer from a list provided (e.g. ‘yes’ or ‘no’).
3. Open-closed questionnaire: in this type of questionnaire, the respondent is asked a closed question (to be answered ‘yes’ or ‘no’) followed by an open question (e.g. ‘why?’) that allows the respondent to give his/her personal opinion.

At the designing stage of a questionnaire, researchers need to decide whether to ask open or closed questions according to their research objectives. As noted above, open questions allow respondents to answer in their own words, affording them flexibility in how they provide any answers, but drawing unstructured responses. Closed questions, in contrast, restrict respondents to selecting from the provided answers, but draw structured responses. The choice between open and closed questions depends on the general research problem, the type of data needed by the researcher, and where the researcher wants to place the burden of interpretation (Houtkoop, 2000).

Since one of this study's objectives is to identify and rank the delay factors (risks), an industry survey based on a questionnaire was selected as a method of data collection in this study.

3.4.4 Brainstorming

Brainstorming is a method of generating a list of suggestions about the risks that might threaten a project through bringing together all relevant parties to identify the possible risks. All ideas are evaluated, and a final list is made. In this research study, this technique was used during the case study survey to assign the list of delay factors affecting the critical activity of a construction project (Morano, 2006).

3.4.5 Delphi technique

Delphi is a method of using group judgment in forecasting. A qualified group is consulted and asked to identify risks, or to estimate the impact and probability of identified risks, with the group members kept separate from each other. The risk coordinator designs questionnaires carefully, then summarises the responses and extracts estimates based on the results (Morano, 2006). This process will be repeated until a stable opinion is reached.

The next section discusses the two types approaches used for risk analysis such as qualitative and quantitative risk analysis.

3.5 Qualitative risk analysis

Qualitative risk analysis evaluates the significance of the risks identified through the risk identification process, and allowing the risks to be categorised for further analysis (Anderson et al, 2005). Each identified risk is assessed for its possibility of occurrence and impact on a project. The product of these assessments provides an overall measure of frequency and severity of risk; however, a higher risk rating indicates a more important risk (Ward, 1999).

There are several advantages and disadvantages of the qualitative risk analysis approach. The main advantage is that it assists in prioritising the risks and identifying areas for immediate action and improvement. On the other hand, the disadvantage of qualitative risk assessment is that it does not provide specific quantifiable measurements of the magnitude of the impacts; therefore making a cost-benefit analysis of recommended controls more difficult (Ward, 1999).

3.6 Quantitative risk analysis

Quantitative risk analysis generally follows the qualitative risk analysis phase. Quantitative risk analysis focuses on quantifying the impact of risk factors on the activities of a project. The aim of the quantitative risk analysis is to identify the possible risk coverage related to a project and to assist the construction manager in developing suitable and effective responses for risk mitigation (Qiu, 2001). The quantitative methods use different methods for analysis throughout the project duration. The most popular methods used in network analysis are Critical Path Method (CPM), Program Evaluation and Review Technique (PERT), Probabilistic Network Evaluation Technique (PNET), Monte Carlo Simulation (MCS) and Latin Hypercube Technique (LHT). These methods are discussed in the following sections (Qiu, 2001).

3.6.1. Critical Path Method

The CPM is a planning technique, which is normally used for activities and resource planning (Wickwire et al, 1989). The CPM helps to identify the possible critical activities in a construction project that are affected by critical resources. If some of the activities require other activities to finish before they can start, then the project becomes a complex task to identify critical activities (Antill and Woodhead, 1982).

CPM can help to establish:

- How long your complex project will take to complete;
- Which activities are "critical," meaning that they have to be done on time or else the whole project will take longer to complete.

3.6.2. Probabilistic Network Evaluation Technique

The algorithm used by Probabilistic Network Evaluation Technique (PNET) is based on the different modes of failure that a network can have. Failure is the completion of a project in a time longer than the target duration. Each path in the network can become a mode of failure. Thus, the completion of a project can be delayed by one or more paths in the network. PNET uses the simplified, approximate solution for the combination of modes of failure (Qiu, 2001).

3.6.3. Programme Evaluation and Review Technique

The Programme Evaluation and Review Technique (PERT) is a risk analysis and management tool used to schedule, organise and coordinate tasks within a project. It is basically a method to analyse the tasks that are involved in completing a given project, especially the time needed to complete each task, and to identify the minimum time needed to complete the total project. The PERT relies on a formula for combining the estimates of three cases for an activity (Qiu, 2001) namely:

1. An optimistic time, which is considered to be the ‘best’ time given that all associated factors fall into place;
2. A pessimistic time, which is the ‘worst-case’ scenario, with everything going wrong which could go wrong;
3. A most-likely duration, which is the ‘normal’ time for the activity, based upon expert judgment, experience or other factors.

According to PERT, Expected time = (Optimistic + 4 x Most likely + Pessimistic) / 6.

3.6.4. Monte Carlo Simulation

A large number of computer software programs are available to support schedule and cost-risk analysis. Most of the existing software involves the use of Monte Carlo Simulation (MCS), though some companies and organisations have developed their own risk analysis software (Qiu, 2001).

The MCS is a simulation method which is widely used for generating random numbers to a given sample, having the random effect of possibility of occurrence. It is applicable for simulating different types of complex problems which mainly involves random performance. There are also different types of algorithms that exist to generate random numbers, considering a wide range of probability distributions. In general, MCS methods are generally utilised in solving various mathematical problems through the generation of random numbers (Berg, 2004). Figure 3.2 shows a typical risk distribution of a selected project using the MCS.

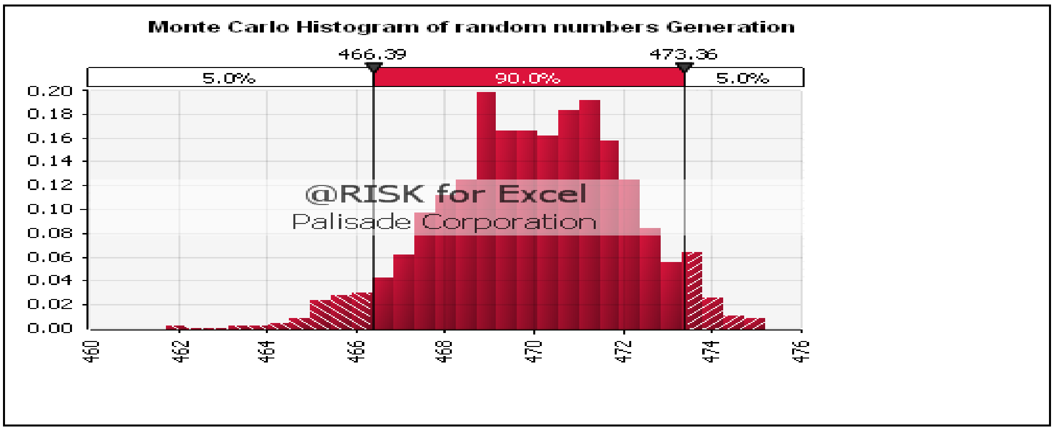


Figure 3.2 shows distribution of a risk generated by using MCS

Monte Carlo simulation is used to determine the impact of the risk factors linked with a project completion time using statistical simulation. Monte Carlo simulation does this hundreds or thousands of times, and the result is a probability distribution of possible outcomes. In this way, Monte Carlo simulation provides a much more comprehensive view of what may happen. It provides information about what could happen and how likely it is to happen (Qiu, 2001). Monte Carlo simulation provides a number of advantages in the risk analysis, as follows:

Probabilistic Results: This result provides information on the possibility of how and when an occurrence may happen. When certain outputs occur using Monte Carlo simulation, it also provides analysis of the inputs, which is important for conducting further analysis.

Graphical Results: The Monte Carlo simulation also produces graphical results of different types of outcome and their possibility of occurrence. This is vital to communicate the simulation results amongst stakeholders.

Sensitivity Analysis: Analysis with deterministic values makes it hard to visualise the impact of risk. However, the Monte Carlo simulation helps to visualise and communicate the outputs that have a significant effect on inputs. Sensitivity results can be presented in text, tables or graphs (Marshall, 1988).

Correlation of Inputs: Since the Monte Carlo simulation has the flexibility to model the dependent interactions between input factors, this simulation method provides better accuracy when showing how and when some risk factors go up and down.

3.6.5. Latin Hypercube Technique

According to the statement highlighted in the risk software, the Latin Hypercube Technique (see Figure 3.3 below) is a new development as a data sampling technology. It has been developed to rebuild the input distribution more accurately through sampling, with a lower number of iterations in comparison to the Monte Carlo method. Stratification of the input probability distributions is the key for this technique. The stratification process splits the cumulative curve into equal intervals on a scale of cumulative probability between 0 and 1.0. A recreated sample is then selected randomly from each interval as part of the stratification of the input distribution. The sampling is affected to represent values in each interval, and, thus, it is forced to recreate the input probability distribution (Risso et al, 2011).

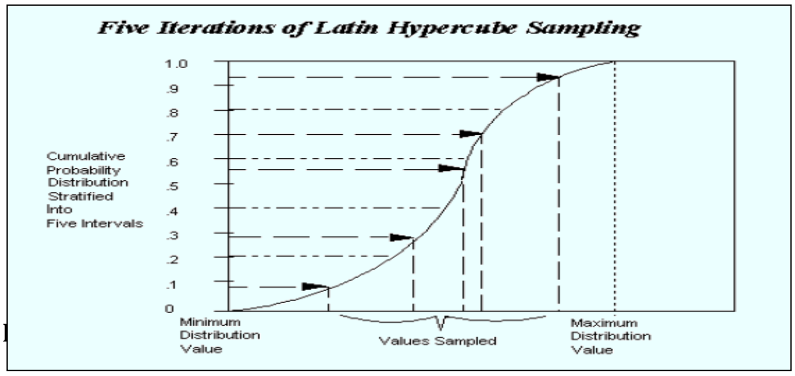


Figure 3.3: l

3.6.6. Advantages and disadvantages of quantitative risk analysis

The major advantage of quantitative risk assessment is that it provides a measurement of the impacts of magnitude, which can be used for further analysis. The disadvantages are the numerical ranges used to express the measurement, as a result of which the meaning of the quantitative risk assessment may be unclear. The requirements of the results are to be interpreted in a qualitative manner, and additional factors must be considered to determine the magnitude of the impact (Boehm, 1991).

3.6.7 Generation of random number

Probability distribution of a random number mean is the statistical function that describes all the possible values that a random variable can take within a given range (Edwin, 2003).

Random numbers for each delay factor are generated from a particular representative distribution. Using Monte Carlo simulation techniques, the random values are generated between minimum and maximum (0 to 1) in relation to the risk probability of each delay (risk) factor. The generation of a random number depends on the selected distribution type of risk factors (Dawood, 1998). The behaviour of each risk (delay factors) can be simulated through a distribution function. In risk simulation, the first step is to select the distribution function. Then, the next step is to identify the mean duration for each activity by selecting the pattern or the distribution of the delay (risk) factors throughout the activity duration.

The formula to calculate the mean duration varies according to the types of distribution functions. The distribution type controls the risk occurrence probability since it is different from one project to another. The type of distribution can vary from one activity to another activity; therefore, there are different types of distribution, ranging from uniform, triangular, beta and normal distributions to more complex forms (Dawood, 1998). The commonly used distribution types of risk factors are explained as follows.

Uniform – All values have an equal chance of occurring, and the users simply need to define the minimum and maximum. Examples of uniformly distributed risk factors are design changes or incomplete design scope. An example of a uniformly distributed risk (delay) factor is shown in Figure 3.4.

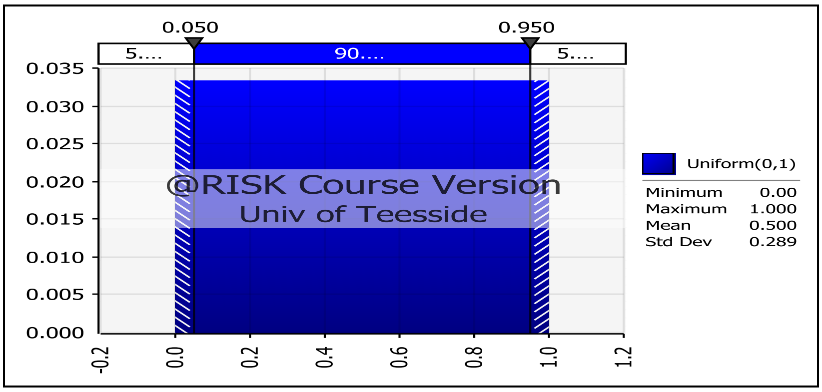


Figure 3.4: shows uniform distribution of a risk factor

Triangular – the triangular risk distribution is used where the outcome is between two extremes and the tendency is towards one outcome. In this type of distribution, the user needs to define the minimum, most likely, and maximum values. Values around the 'most likely' are more likely to occur. Risk factors that could be described by a triangular distribution are weather condition, labour productivity and materials delay. For example, triangular distribution is shown Figure 3.5.

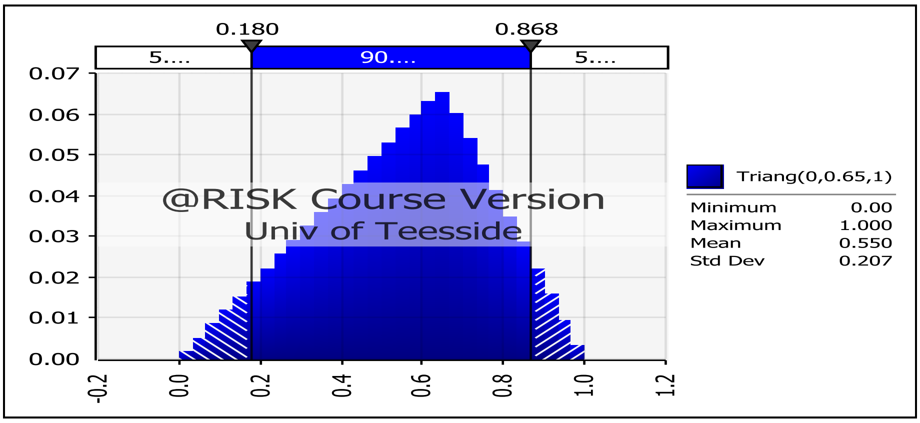


Figure 3.5: shows triangular distribution

Normal or "curve" – In such a type of risk distribution, the user simply defines the mean or expected value and a standard deviation to describe the difference about the mean. Values in the middle near the mean are most likely to occur. Examples of normal distribution used in different risk factors are subcontractor performance and project team availability (see Figure 3.6).

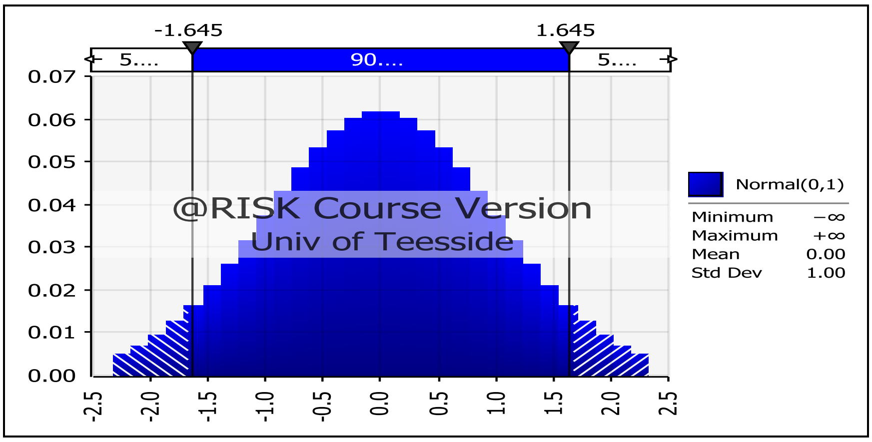


Figure 3.6: show normal distribution

Pert or "beta" – in this case of distribution, the user needs to define the minimum, most likely and maximum values, just like the triangular distribution. Values around the 'most likely' are more likely to occur. Materials delay or soil conditions are examples of beta distribution (see Figure 3.7).

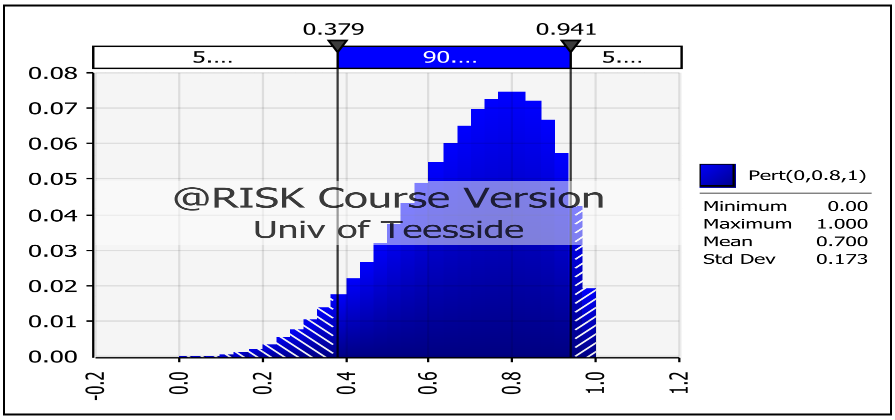


Figure 3.7: show beta distribution

3.7 Risk Response Planning

Thomas et al (2004) highlighted how risk response planning mainly pays attention to high-level tasks, which are evaluated by both the qualitative and/or quantitative approaches of risk analysis. The risk response planning process helps to identify which approach is suitable for each risk, and then proposes a specific action for implementation according to the identified approach. Approaches used in risk response planning are as follows (Thomas et al, 2004):

- **Avoidance** – this helps to remove the uncertainty that the risk may occur by reducing the probability to zero through executing the project in a different way. The aim of avoidance is to protect activities from the impact of risk, for example by expanding a schedule or adding resources in the critical activities. However, few risks arise at the early stage of a project, and they can be prevented by clarifying requirements, obtaining information, improving communication and acquiring expert advice.

- **Transference** – this action helps to shift the negative impact of a risk to another party, by identifying another stockholder who has a better ability to manage the risk, and to whom the responsibility for the action can be passed; an insurance policy, for instance.

- **Mitigation** – this action helps to reduce the size and impact of the risk level, accepting the risk to the project or organisation, but reducing its probability. Reducing the impact of a risk on the project is regularly more effective than repairing the damage after its occurrence. Examples of mitigation actions include adopting less complex processes, conducting more tests, or choosing a more stable supplier in a project.

- **Periodical reports –** these are assigned for each risk, to decide the usefulness of the plan. The unanticipated effects and corrections must be taken into account to mitigate the risk. Since this phase has high significance, this step cannot be underestimated.

- **Contingency plan –** planned measures designed to be executed when an anticipated risk occurs.

- **Acceptance** – in practice, the project manager and the project team normally decide to allow certain risks where they cannot change the project plan to deal with a risk or identify any response strategy. This strategy can be either passive acceptance, without requiring any actions, or leaving the project team to monitor the status of the risks. This strategy also helps to deal with the possible risks that may occur, or accepts them by developing an appropriate emergency plan, including the amounts of time, money or resources required to handle such risks.

3.8 Monitoring and controlling risks

The monitoring and controlling of risks is the last phase/stage of the risk management process, which keeps track of the existing and new risks that have been identified, makes sure that the agreed responses are properly implemented, and reviews their effectiveness. This also includes monitoring changes in risk throughout the project. Since the identified list of project risks changes as the project matures, new risks may develop, existing ones disappear, or the impact of risk might be greater than expected (Thomas and Donald, 2003). In such circumstances, the planned response may not be enough, and additional responses need to be planned to control the unexpected risks. The processes involved in the risk monitoring and controlling stage are therefore as follows:

- Selecting alternative approaches;
- Applying a contingency plan;
- Adopting corrective actions;
- Modifying the project management strategy.

The significance of this phase must be taken into account in order to ensure the effective monitoring of risk management, and to avoid the failure of the entire process.

3.9 Chapter summary

This chapter presented the overview of the risk management processes. It included detailed discussion of each process that needs to be considered in order to analyse and manage the possible risks in a project, and presented the basic steps necessary in the form of a flow diagram. Risk identification is the first step in the risk management process, since a project is exposed to different types of risk at all stages and different techniques are required to identify and analyse the risks. Checklists, interviews with individuals or groups, brainstorming, or using Delphi technique are the key techniques which are used in the risk identification process, and these have been discussed in this chapter. In many cases, the project risks are identified and quantified, and the chapter explained the qualitative and quantitative risk analysis techniques.

Moreover, a risk response plan was discussed, in addition to risk monitoring and control planning. For a successful management of risk, all risk management processes discussed in this chapter must be followed for any types of project that are considered for risk analysis and management. In this study, both qualitative and quantitative risk analysis techniques were used to analyse the delay risk in a building construction project. The next chapter explains the research methodology adopted in this study.

Chapter 4-

Construction Industry Survey

Chapter 4: Construction Industry Survey

4.0 Introduction

Previous chapters introduced the research study and a literature review of identification and analysis techniques for reviewing delay risks associated with construction projects. This chapter discusses the methodology adopted in the study, outlines some of the available methods for carrying out industry surveys, and highlights their known limitations. The main objectives of the industry survey were to identify the existing practices, techniques and software being used; to understand the problems associated with delay factors; and to note any existing use of delay analysis modelling and simulation practice in analysing and quantifying the impacts of delay factors in construction projects. This chapter also includes the details of the construction industry survey, which presents a comparative study of delay factors in construction projects between a developing (Libya) and developed (the UK) country. The findings from the industry survey were used to design the framework of the delay analysis system, which is discussed in Chapter 5. The next section starts with the brief description of the research methodology.

4.1 Research methodology

4.1.1 Overview

From the literature review, it was found that there are two basic research approaches: quantitative and qualitative. The quantitative approach includes the generation of data in quantitative form using quantitative analysis in a suitable way, whereas the qualitative approach depends on subjective decisions, which are based on attitudes, opinions and behaviour (Kothari, 2008). The simulation approach, which is part of the quantitative approach, is useful in developing models for tackling future circumstances. Moreover, Fitzgerald et al (2002, cited in Shah, 2011) highlighted that system modelling is a technique and an idea for system development. This approach is normally utilised in the development of computer-based modelling because of rapid delivery of the systems and the precise determination of system requirements (Dennis et al, 2008, cited in Shah, 2011). Therefore, the modelling of the delay analysis system was selected as the research methodology to accomplish the aim of this research study. Other techniques, including a literature review, a construction industry survey using semi-structured interviews, development of a model, and the demonstration and validation of the model functionalities with case studies, were utilised to achieve the research objectives.

Furthermore, Addis and Talbot (2001) defined research methods as "a systematic and orderly approach taken towards the collection of data so that information can be obtained from those data". Considerable thought was given to the selection of research methodology prior to commencement so that the research could be conducted in as systematic a way as possible. The main focus was kept particularly on the essential aspects of research, which can be regarded as being "searching by means of careful, critical investigation in order to discover something specific" (Barton et al, 2000).

Bounds et al (1994) pointed out that whilst questionnaires have an advantage in saving time and money in conducting research, the method lacks the flexibility of being able to adapt the question where appropriate to gain an understanding of the subject. An additional complication occurs when a business is approached in relation to a questionnaire survey, because the researcher typically wants to have a detailed discussion about the issues on a far more sophisticated level than a questionnaire could produce.

4.1.2 Qualitative and quantitative approach

Both qualitative and quantitative approaches are used in the research study since the objectives of the study and the nature of the questionnaire involve both qualitative and quantitative analysis. Blois (2004) defined the qualitative method as an array of interpretative techniques, which seek to describe, decode and translate terms with the meaning, not the frequency, of certain more or less naturally occurring phenomena in the social world; in contrast, quantitative research is used to measure attitudes, satisfaction, commitment, and a range of other useful aspects that can be tracked over time. Such an approach is also used as part of a wider business planning and business strategy process. Additionally, quantitative research has a rational and linear structure in which a hypothesis takes the form of a belief about likely causal links between the ingredients and concepts identified.

4.1.3 Quantitative method

A quantitative research methodology is appropriate where quantify able measures of variables of interest are possible, and where hypotheses can be formulated, tested and inferences drawn from samples to populations (Parkin, 2000). Quantitative research is primarily based on positive thought while qualitative research is more constructivist theory. Recently, the strict scientific methods employed by quantitative analysis have been considered the best way to conduct any meaningful research. However, current thought holds that the two paradigms are not mutually exclusive and could very well support each other in most social science inquiry.

4.1.4 Qualitative method

Qualitative methods are appropriate when the phenomena under study are “complex, social in nature, and do not lend themselves to quantification” (Blois, 2004). Direct and in-depth knowledge of research is necessary to achieve contextual understanding. As a result, qualitative research methods are associated with “face-to-face” contact with people in the research setting, together with verbal data and observations. Qualitative research is a means for describing and attempting to understand observed regulation, patterns, commonalties and themes in what people do, say and report as their experience, and is focused on natural settings. The method used by qualitative researchers exemplifies a common belief that they can provide a deeper understanding of social phenomena than would be obtained from purely quantitative data (Parkin, 2000).

4.1.5 Secondary data

Secondary data to inform the current research was also obtained from different sources, including e-resources (the Internet), past research projects, journals and books. The Internet provides access to a wide variety of different types of secondary data that can be used to support the research (Barnett, 2002).

4.1.6 Questionnaire

A questionnaire is a technique to collect data/information from a potentially large number of respondents. This is the only feasible means to achieve a number of responses large enough to allow statistically valid analysis of the results. A well-designed questionnaire can gather information on both overall performances and specific components of the test system. If the questionnaire includes demographic questions of the participants, these can be used to correlate performance and satisfaction with the test system among different groups of users or locations.

It is important to keep in mind that a questionnaire should be viewed as a multi-stage process beginning with definition of the different aspects to be examined and ending with interpretation of the results. Every step needs to be designed carefully because the final results are only as good as the weakest link in the questionnaire process. Although questionnaires may be economical to administer compared to other data collection methods, they are every bit as expensive in terms of design time and interpretation (Houtkoop, 2000).

4.1.7 Interviews

Interviews can be structured or unstructured, depending on the situation of the interviewer. In a project where the interviewer has more contact with the organisation they may do unstructured interviews, whereas in a structured interview the interviewer uses a questionnaire to ask respondents questions face to face (Houtkoop, 2000). The next section discusses the survey of construction industry professionals using a questionnaire, and the analysis of the data using both quantitative and quantitative methods.

4.2 Background to construction industry survey

This section discusses the existing techniques and practices used for collecting and analysing data through an industry survey. Questionnaires are the main technique used for gathering data from a potentially large number of respondents. It is widely accepted that this is a feasible means to achieve wide range of views or opinions from construction professionals, and to provide data that can be analysed statistically to deliver the required findings.

It is important to retain in mind that a questionnaire should be viewed as a multi-stage process, start with definition of the different aspects to be examined and ending with clarification of the results. Questionnaires may be economical to administer compared to other data collection methods, such as interviews and focus groups, but they are bit more difficult in terms of design, time and the interpretation of findings. Several types of question were used in the design of the questionnaire for this study (see section 3.4.3 in Chapter 3), but a pilot study was conducted before designing the formal questionnaire and conducting the industry survey.

4.2.1 Pilot study

According to De Vaus (1990), a pilot study is a necessary task in any research process, enabling the researcher to measure the reliability and validity of indicators (variables). In this study, the pilot study comprised questionnaires using a sample similar to that of the main survey. Therefore, the questionnaires for the pilot study were distributed via the Libyan Embassy to UK-based Libyan students with a construction industry background.

The pilot study was very valuable in revealing the level of constraints in gaining access to sources of data and information. Furthermore, it allowed the application and examination of the research strategy and methodology to be tested in the context of the study. It also gave real insight into sources of data in terms of their availability and accessibility.

4.2.2 Sampling

Social scientists use many different sampling strategies to find a representative sample, and there are different types of sampling techniques. In general, the determination of a sampling technique depends on two factors: the degree of accuracy required in the study, and the cost (Smith, 1991). In this study, the selection of a sampling method was based on the need to avoid a biased sample, the time available, and the circumstances of the study. The random sampling method was adopted in the industry survey since this method ensures that each sample has equal chance of being selected for questioning, considering different locations. It is practically difficult to get data from all the professionals in the UK and Libyan construction industries. Normally, work with a carefully selected sample is called experimental units, with the sample having characteristics that are different from the overall population. The best way to get an equal representative sample is to choose a proportion of the population at random without bias, with every possible experimental unit having an equal chance of being selected. A random sampling method was adopted for the distribution of the semi-structured questionnaires, with questionnaires distributed to randomly selected construction professionals in the UK and Libyan construction industries.

4.2.3 Questionnaire design

In this study, questionnaire design was informed by the literature surveys conducted by previous researchers (Assaf and Al-Hejji, 2006; Wael et al 2007; Odeh and Battaineh, 2002; Zaneldin, 2006) in relation to delay analysis in construction projects. The questionnaire developed in the study was divided into three parts:

- Part one was related to general information of the respondent’s experience and associated company. Contractors, owners and consultants were requested to answer the questions pertaining to their experience in the construction industry and to give their opinions about the percentage average time delay in projects that they experienced.

- Part two related to respondents’ experience of project performance.

- Part three included the list of seventy-five delay factors, identified from the earlier literature review. These factors were further classified into four categories and eight sub-categories according to the sources of delay.

Delay factors related to project, owner, contractor, consultant, materials, equipment, manpower (labour), project management and external factors were included in the questionnaire. Questions relating to each delay factor were grouped into two categories: frequency of occurrence and severity impact level, each on a four-point Likert scale. Frequency of occurrence was categorised on a 1 to 4-point Likert scale as follows: never; occasionally; frequently; and constantly. Similarly, degree of severity was categorised on a 1 to 4-point Likert scale as follows: no effect; fairly severe; severe; and very severe. The questionnaire was printed in two languages –English and Arabic – in order to collect the responses from both the UK and Libya. To obtain a high level of response, the following points were considered during the design of the questionnaire:

- A covering letter was attached with questionnaires;
- The type of research, sponsoring organisation and the researcher's name were mentioned in the cover letter;
- The purpose and the benefits of the study were highlighted in the cover letter;
- The participants were informed that their name, department or company name would be kept confidential in the research;
- The questionnaire was presented in a smart and attractive design;
- The questionnaire was designed to be as short as possible, so that it could be completed within 15 to 20 minutes. Appendix-A includes the covering letter, questionnaire and questionnaire form that were distributed to Libyan and UK construction companies.

Because of the cultural differences between the UK and Libya, it was decided to use an appropriate distribution method for each country.

In Libya:

Because the mother tongue of most people working in construction in Libya is Arabic, it was necessary to provide the questionnaire in the Arabic language. However, some English terms are commonly used in the Libyan construction industry. For speed of response, the questionnaires were distributed personally and collected by hand. This method was effective, as there was direct communication between the researcher and respondent.

In the United Kingdom:

The questionnaires were distributed to construction companies by post. Apart from the simple style and structure of the questionnaire, three points were considered in the postal questionnaire to guarantee a fast and high level of response:

- A reply envelope was provided inside each letter;
- A stamp was affixed to each reply envelope;
- Return address labels were used on the envelopes.

4.2.4 Questionnaire distribution

The questionnaires were distributed to owners, consultants and contractors working in the Libyan and UK construction industries. The survey covered different UK towns and cities such as Cardiff, Chester, Stockton, Bristol, Lancaster, Leeds, London, Manchester, Hull, Coventry, Sheffield, Edinburgh and York, in order to reduce location bias. Similarly, the survey questionnaires were distributed in different Libyan cities such as Tropile, Zawa, Zwara, Al Khums, Sabratah, Masratah, Ben-Walled, Sirt and Ben-Gazee. These cities were selected since they are the most important regions in Libya, both in terms of the concentration of the population, and in terms of social, economic and construction activities. Moreover, recent statistical indicators showed that some of these cities in Libya have been the largest and fastest growing cities in the country (Jumaili, 2008).

4.2.5 Survey data collection

A total of 300 questionnaires were distributed randomly amongst the selected companies for the industry survey: 175 distributed in the UK by post; and 125 distributed in Libya by the researcher in person. A total (116) 38.66% responses were received from the participating companies/professionals, with a response rate in the UK of 37.9% and in Libya of 62.1% (see Table 4.1 and Figures 4.1 and 4.2).

Table 4.1: Numbers of questionnaires distributed and responded to in the UK and Libya

Questionnaires	Contractors			Consultants			Owners			Total
	L	UK	Total	L	UK	Total	L	UK	Total	
Distributed	38	68	106	45	57	102	42	50	92	300
Respondents	24	13	37	20	19	39	28	12	40	116
Percentage of Responses from both countries	31.9%			33.6%			34.5%			38.66%

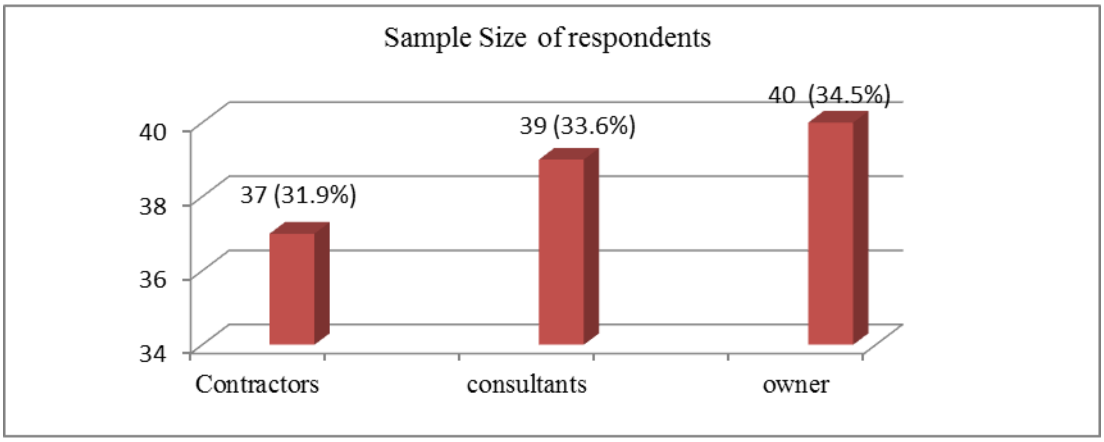


Figure 4.1: Sample size of respondents

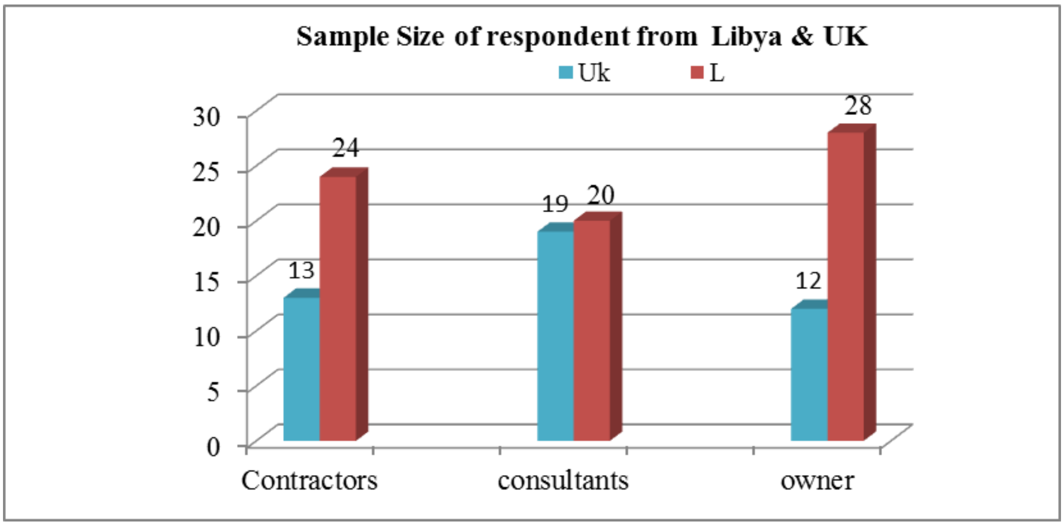


Figure 4.2: Sample size of respondent from Libya and the UK

4.3 Data analysis techniques

Descriptive and frequency statistical analysis techniques were used to analyse the data collected in the survey of the construction industry. However, an advanced and accurate method is necessary to analyse the large body of data in a systematic, fast and reliable way. For this purpose, the computer software Statistical Package for Social Science (SPSS 16) and MS Excel were selected. In section three of the questionnaire, respondents were asked to rank the delay factors in terms of their frequency and severity weight. The scales provided ranges from 1 to 4 as shown in Table 4.2 below. However, in order to open a quantitative measure of the frequency and the severity, it was decided to weight the factors with the same weight that was assigned to them.

Table 4.2: Frequency and severity weighting scale

Scale	Frequency (F)	Weight	Severity (S)	Weight
1	Never	1	No effect	1
2	Occasionally	2	Fairly severe	2
3	Frequently	3	Severe	3
4	Constantly	4	Very severe	4

The data collected from the survey were analysed using a frequency and severity index method (Assaf and Al-Hejji, 2006). The details of both frequency and severity index analysis are explained below.

According to Assaf and Al-Hejji (2006), a formula as shown in equation (1) was used to rank delay factors based on frequency of occurrence as identified by the participants, which is called Frequency Index (F.I.).

$$(\text{F.I.})(\%) = \sum_{a=1}^{4} a(n/N) * 100/4 \quad \ldots\ldots (1)$$

Whereas; a is the constant expressing weighting given to each response (ranges from 1 for never up to 4 for constantly), n is the frequency of the responses, and N is total number of responses.

Similarly, a formula as shown in equation (2) was used to rank delay factors based on severity degree as indicated by the participants, which is called Severity Index (S.I.).

$$(\text{S.I.})(\%) = \sum_{a=1}^{4} a(n/N) * 100/4 \quad \ldots\ldots (2)$$

Whereas; a is equal to the constant expressing weighting given to each response (ranges from I for no effect up to 4 for very severe), n is the frequency of the responses, and N is total number of responses.

Importance Weight: The importance index of each factor is calculated as a function of both frequency and severity indices, as shown in equation 3:

$$IW = [F.I.(\%) * S.I.(\%)]/100 \quad \text{..........} \quad (3)$$

4.4 Findings of construction industry survey

This section discusses the findings from the industry survey, which are presented in three sub-sections: general information about respondents; background to construction project; and identification of delay factors. The next sections present and discuss the findings relating to respondents' experience, contractual arrangements, and the performance of their projects.

4.5 Section one: respondents' experience

4.5.1 Type of business

This section presents general information about the respondents who completed the survey. The aim of this section is to provide background regarding the respondents' experience, and therefore to indicate the degree of reliability of the data provided by them.

Table 4.3: Respondents by type of business in the construction industry

Type of business	Country		Total	Percent
	Libya	UK		
Contractor	24	13	37	31.9%
Consultant	20	19	39	33.6%
Owner	28	12	40	34.5%
Total	72	44	116	100.0
Percent	62.1%	37.9%	100	

Table 4.3 indicates the number of respondents who participated in this survey. Each respondent was asked to select his/her business in the construction industry. As noted

before, the total number of respondents participating in the survey was 116. Of these, owners were the highest number, with 40 participants (34.5%), 28 from Libya and 12 from the UK. Consultants came in the second position, with 39 participants (33.6%); of these, 20 were from Libya, and the remaining 19 from the UK. Finally, the smallest numbers of respondents were contractors, with 37 participants (31.9%). 24 out of the 37 contractors were from the Libyan construction industry and the rest (13) from the UK (see Figures 4.3 and 4.4).

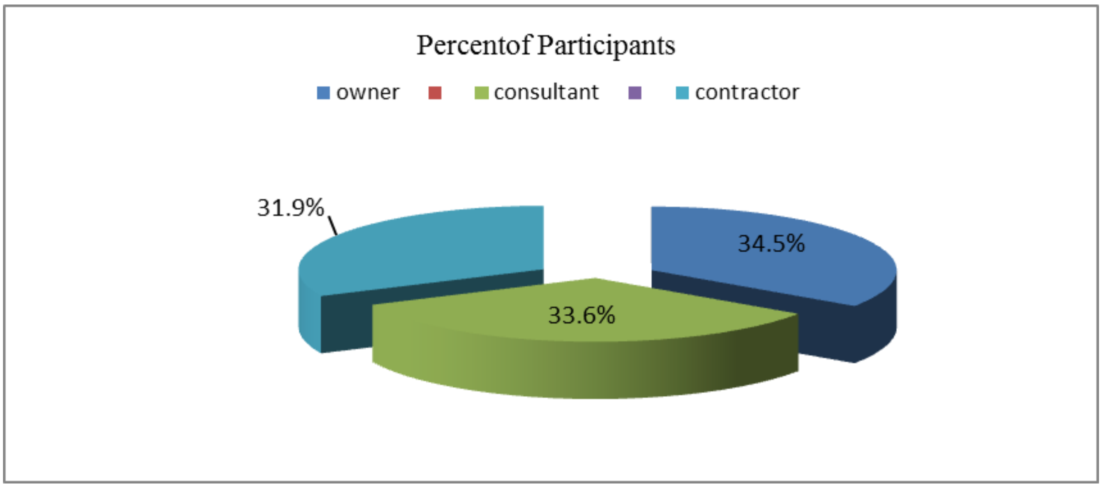


Figure 4.3: Percentage of participants by business type

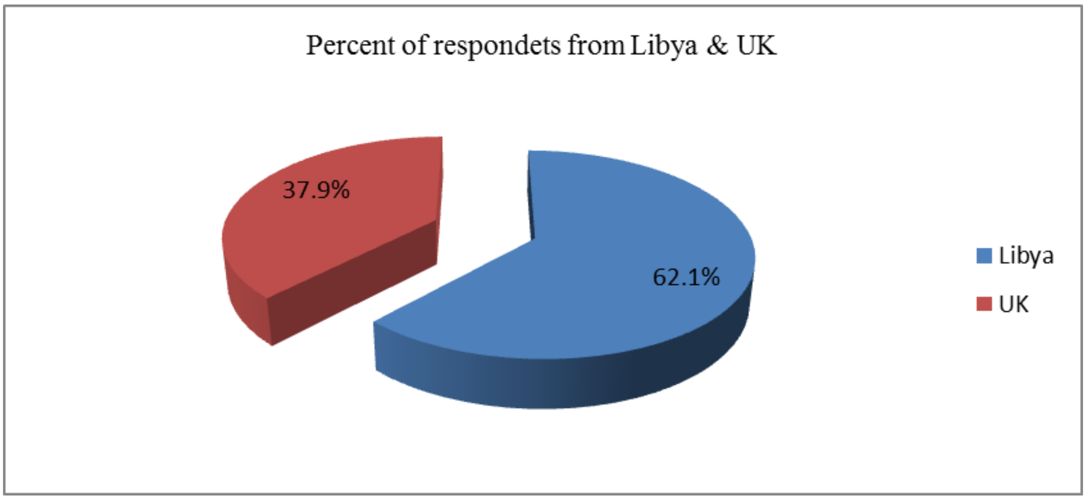


Figure 4.4: Percentage of participants by location (Libya & UK)

At the level of total participants of each country, Libyan respondents were 62.1% of all participants, while the participants of UK form 37.9%.

4.5.2 Type of organisation

Respondents were asked to specify the type of organisation at which they worked. Table 4.5 shows that the vast majority of respondents (58 of 116) were working in the public sector, including 49 from Libya and 9 from the UK. Of the 31 working in the private sector, 15 respondents were Libyan and 16 from the UK.

Table 4.4: Respondents by type of working organisation

Country	Type of work			Total
	Public	Private	Both	
Libya	49	15	8	72
UK	9	16	19	44
Total	58	31	27	116

The smallest group was the 27 respondents working in both the public and private sectors, including 8 from Libya and 19 from the UK. Figure 4.5 show the types of participants' work in relation to their respective countries.

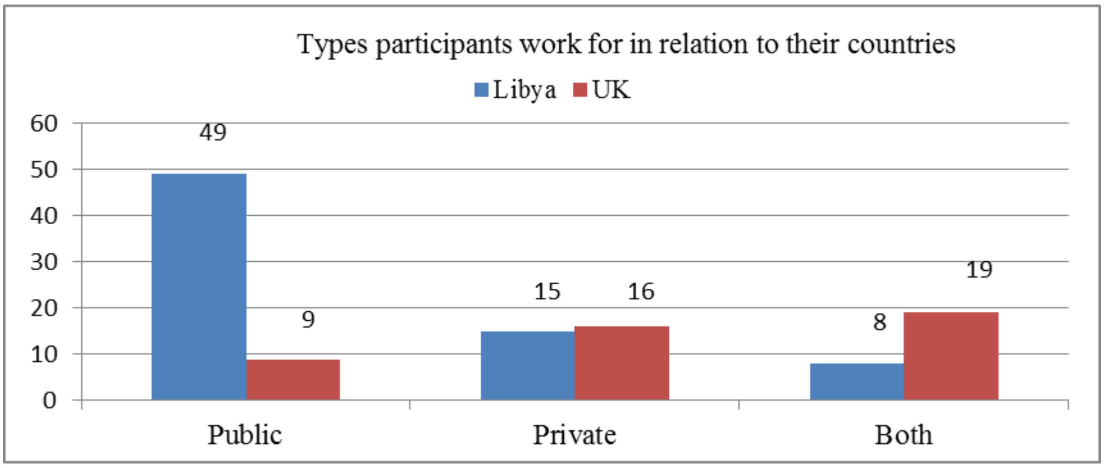


Figure 4.5: Types of participants' work in relation to their countries

4.5.3 Years of experience

Fortunately, of the largest proportion of professionals who participated in the survey have more than 16 years of experience in the building construction industry, which reflects well on the reliability of the data collected.

Table 4.5 Number of years' experience

Country	Years of experience				Total
	<5 years	6- 10 years	11-15 years	>16 years	
Libya	7	13	27	25	72
UK	5	16	9	14	44
Total	12	29	36	39	116

Table 4.5 and Figure 4.6 show the years of experience of the respondents. It shows that 33.7% of the participants (39 respondents) had experience of over 16 years, and 31.1% (36 respondents) between 11 to 15 years. Of those remaining, 29 (25%) had experience of between 6 and 10 years, whereas 12 (10.35%) had less than 5 years of experience.

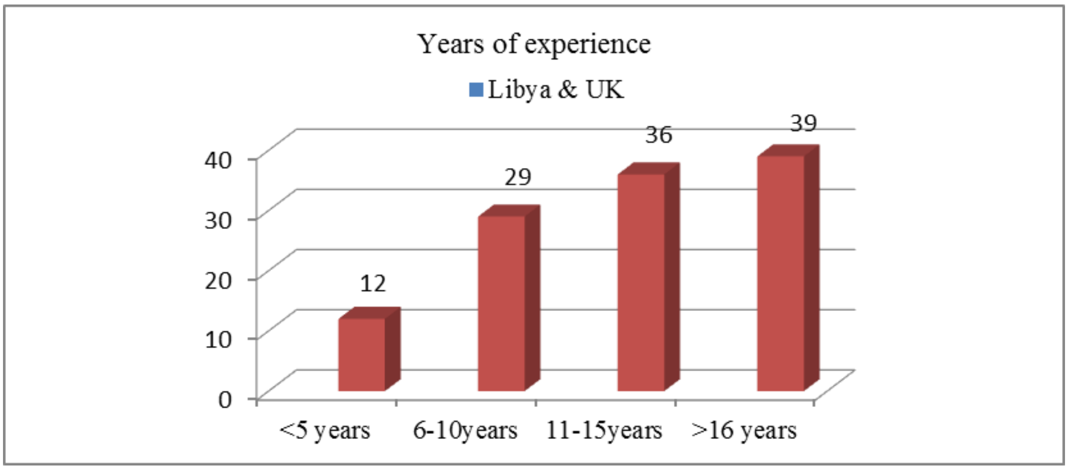


Figure 4.6: Respondents' years of experience in construction

4.5.4 Construction industry speciality

Table 4.6 and Figures 4.7 and 4.8 show the different types of construction projects that respondents were involved in, grouped into major categories. However, since many professionals were specialists in more than one type of construction project, the data analysis includes all the probabilities that were obtained from respondents. This will enable the researcher to take a wide overview of the respondents' experience in addition to presenting the number of respondents for each one of the different categories.

Table 4.6 Construction industry speciality

Construction projects speciality	Country		Total	%
	Libya	UK		
Commercial building	11	7	18	15.52%
Industry building	3	22	25	21.55%
Residential building	35	14	49	42.25%
Government building	23	1	24	20.68%
Total	72	44	116	100%
Different specialisation	Libya	UK	Total	%
Commercial & Industrial buildings	4	2	6	5.17%
Commercial & Governmental buildings	7	8	15	12.94%
Industrial & Governmental buildings	8	3	11	9.48%
Commercial & Residential buildings	10	5	15	12.94%
Governmental & Residential buildings	12	9	21	18.10%
Commercial, Industrial & Governmental buildings	7	4	11	9.48%
Commercial, Governmental & Residential buildings	9	6	15	12.94%
Commercial, Industrial & Residential buildings	5	3	8	6.89%
Commercial, Industrial, Governmental & Residential buildings	10	4	14	12.08%
Total	72	44	116	100%

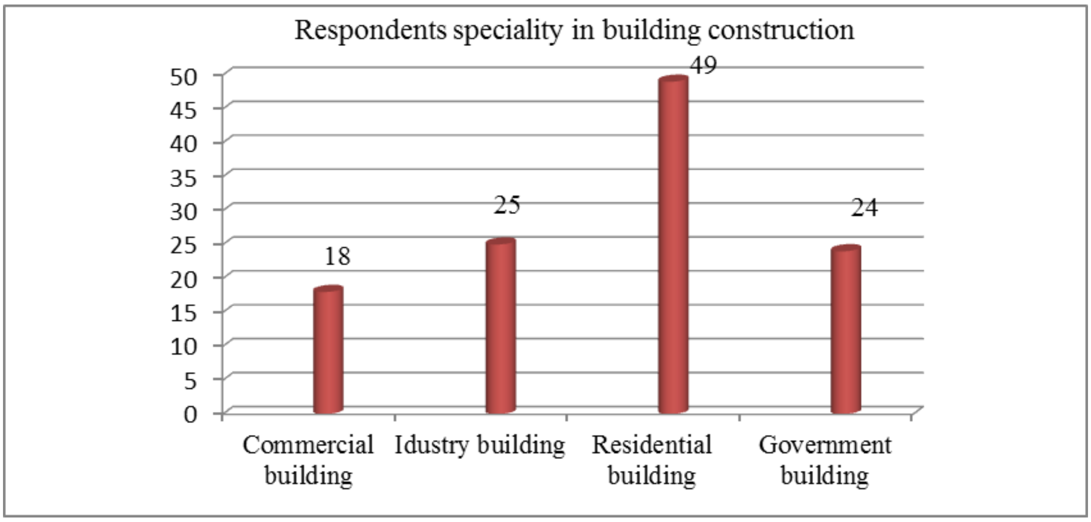


Figure 4.7: Respondents’ specialties in building construction

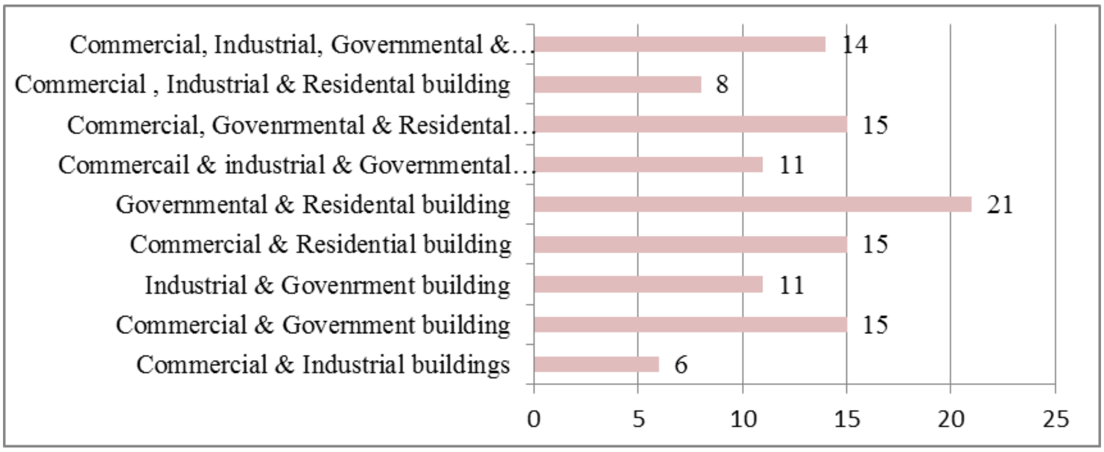


Figure 4.8: Respondents' specialties in building construction - detailed categories

The survey found that the majority of construction companies surveyed were working in residential building, with 49 specialists among the respondents. 25 worked in industrial building, 24 in governmental building, and 18in commercial building. The different types of building were selected in order to understand on depth how delay factors impact upon different types of buildings. The results show that the impact of delay factors is dominated by residential buildings followed by industrial, governmental and commercial building projects. This means that the delay analysis has a higher impact in the case of residential and governmental buildings than in relation to other types of buildings, since the respondents are predominantly from these types of building projects. Hence, the delay impact has less influence in the case of commercial and industrial buildings compared to residential and governmental buildings.

4.5.5 Project sizes

Table 4.7 and Figures 4.9 and 4.10 illustrate respondents' experiences with regard to projects of different sizes.

It shows that the highest number dealt with small- and medium-size construction projects (28), followed by those who dealt with both small and large projects (17). No respondents said that they participated in all sizes of construction projects (i.e. small, medium, large and very large).

Table 4.7: Experience different project sizes they have participated

Size of construction projects	Country		Total	%
	Libya	UK		
Very large (Over £30 million)	3	2	5	4.31%
Large (£16 – 30 million)	16	9	25	21.55%
Medium (£5 – 15 million)	21	18	39	33.62%
Small (Under £5 million)	32	15	47	40.52%
Total	72	44	116	100%
Combination of different sizes of project	Libya	UK	Total	%
Large & Very Large Projects	3	3	6	5.17%
Medium & Very Large Projects	9	6	15	12.94%
Medium & Large Projects	12	3	15	12.94%
Small & Large Projects	11	6	17	14.65%
Small & Medium Projects	16	12	28	24.95%
Medium, Large & Very Large Projects	4	5	9	7.75%
Small, Medium & Very Large Projects	7	3	10	8.62%
Small, Medium, & Large Projects	8	4	11	9.48%
Small, Medium, Large & Very Large Projects	2	2	4	3.50%
Total	72	44	116	100%

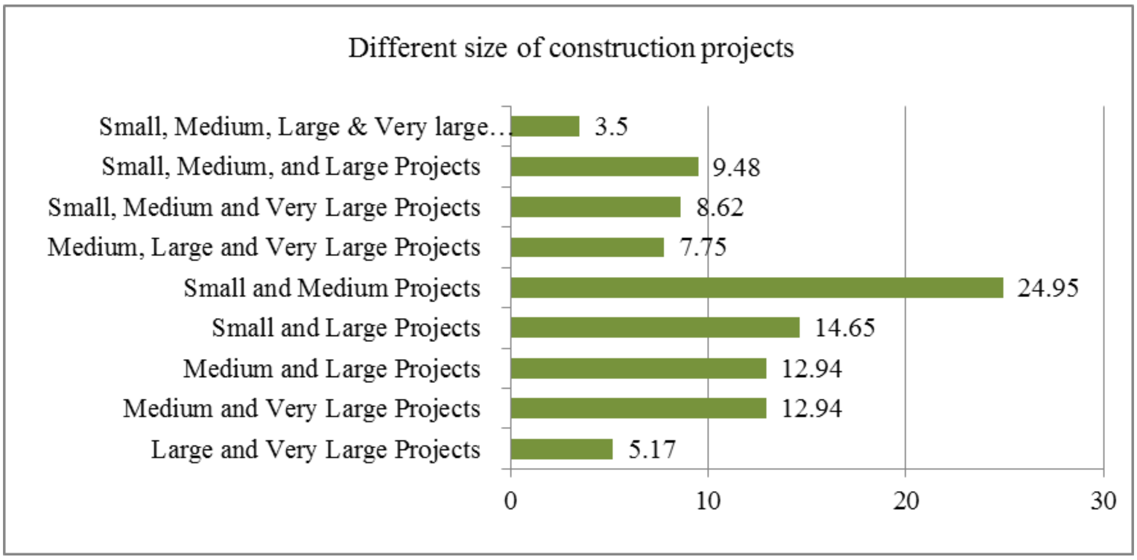


Figure 4.9: Percentages of respondents working in different sizes of projects

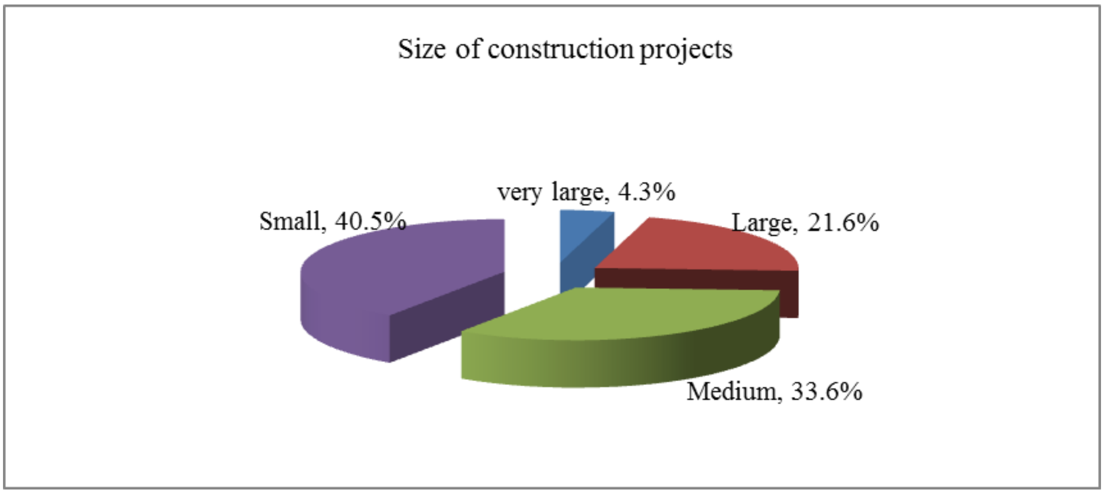


Figure 4.10: Percentages of respondents regarding size of projects

From the survey, it was found that 40.52% out of 116respondentswere working in small-size construction projects, while the proportions working in medium, large and very large construction projects were 33.6%, 21% and 4.31% respectively. This revealed that the size of a project has a direct relationship to the level of impact due to delay factors, since smaller-size projects have less impact compared to bigger-size projects. Since the survey included all types of project and was dominated by small- and medium-sized projects, the results of delay impact have an average effect in analysing the delay factors by minimising the bias of the project sizes. However, the large and very large-size projects have less influence in terms of analysing the delay impact.

4.6 Section two - contractual arrangements

This section focuses on identifying and understanding the existing procurement methods and tendering arrangements in the construction industry so that the impact on project delays due to procurement systems can be analysed. The survey data associated with the procurement system of construction projects in both the UK and Libya was collected through the questionnaire. The findings are discussed by analysing the survey data using suitable statistical tests, as follows.

4.6.1. Procurement methods

Various types of procurement methods are commonly used in construction projects. The questions related to contractual arrangement were distributed to owners and consultants, and the possible methods were grouped into four major categories, since the type and nature of delay factors are different according to the methods of procurements used in building projects. Therefore, all procurement methods were included in the questionnaire to reduce the risk of bias from any one method of procurement that has a high impact in a project when analysing the delay factors. Respondents were asked to select the methods that they had experienced. Table 4.8 and Figure 4.11 show that the type of procurement method most commonly used by respondents was the traditional method, used by 23 participants (29.11%). In contrast, the least-used method was design & build procurement, used by 16 participants (20.25%). Management contracting and construction management procurement methods were used by 18 participants (22.79%), while 22 (27.85%) were involved in projects using the construction management procurement method.

Table 4.8: Procurement methods used by owners and consultants

Procurement methods	Country		Total	%
	Libya	UK		
Traditional	14	9	23	29.11%
Management contracting	7	11	18	22.79%
Design & build	7	9	16	20.25%
Construction management	12	10	22	27.85%
Total	40	39	79	100%

The survey results revealed that delay factors were mainly influenced by traditional methods of procurement followed by construction management, management contracting, and the design and build method of procurement. The design and build method of procurement has less influence when analysing the delay impact, because delays due to design error and approval can be reduced in this method, which is its main advantage compared to the traditional method.

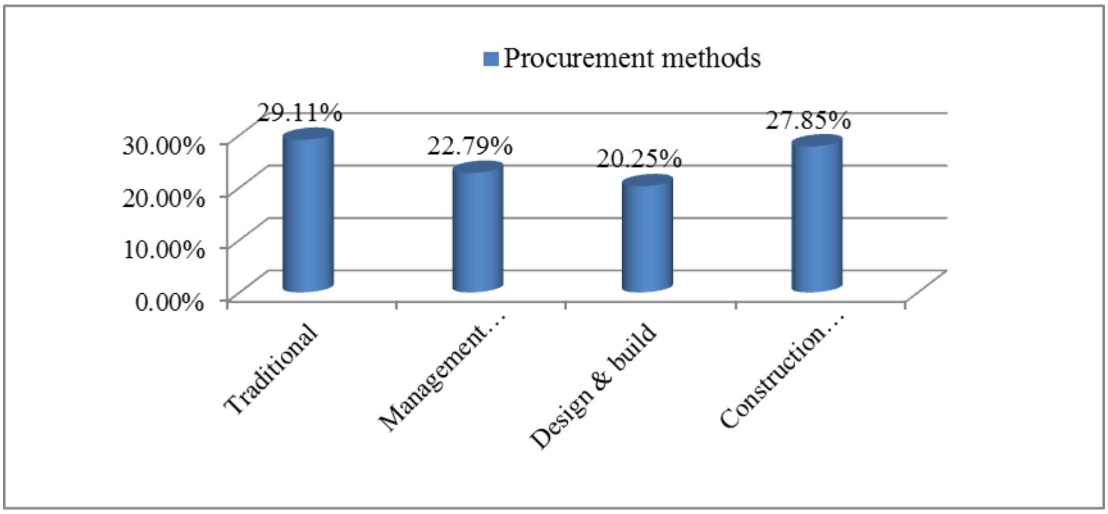


Figure 4.11: Frequency of respondents' involvement in different procurement methods

4.6.2 Tendering arrangements

Table 4.9 presents the survey data related to different types of tendering arrangements. From the survey, it was found that respondents participated in several different types of tendering arrangement. Selective tendering arrangements were selected by 27 respondents (34.17%), while negotiation tendering and continued tendering were each experienced by 16 (20.25%). A further 20 respondents (25.33%) had been involved in projects arranged by open free tender. The details of the different tendering arrangements in which respondents participated are presented in Figure 4.12.

Table 4.9: Frequency of participation in different tendering arrangements (from owner and consultant)

Tendering arrangement	Country		Total	%
	Libya	UK		
Negotiation	9	7	16	20.25%
Open tender	7	13	20	25.33%
Selective tendering	15	12	27	34.17%
Continued tendering	9	7	16	20.25%
Total	40	39	79	100%

Since the tendering arrangement is also a key factor that influencesdelays in a construction project, respondents from different types of tendering arrangements were selected for the studyin order to reduce the bias of any one type of tender arrangement.

The majority of respondents were from selective tendering followed by the open tendering arrangement.

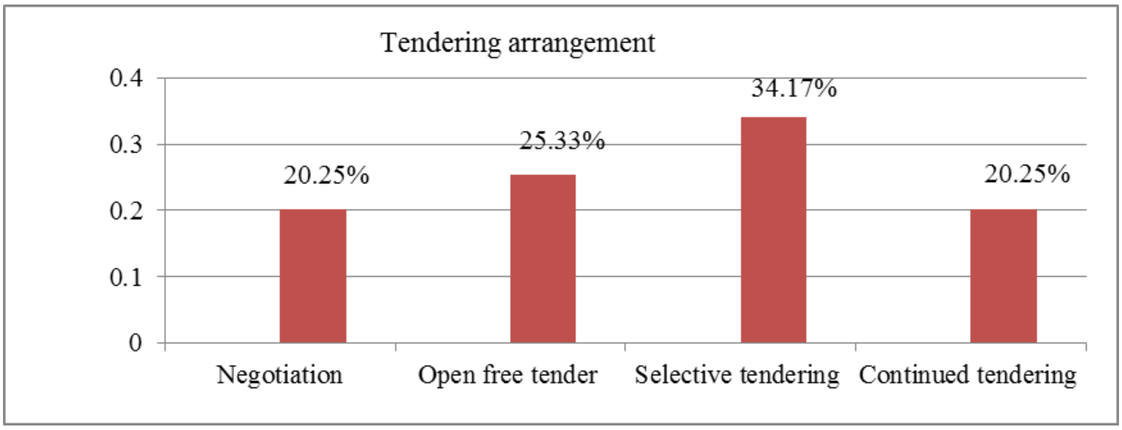


Figure 4.12: Frequencies of tendering arrangements

4.6.3 Number of construction projects

Table 4.10 shows that the contractors and consultants who participated in this survey had been involved in over 1,000 projects. Most respondents therefore had a very broad background in construction projects, which suggests that sharing their knowledge, can lead to accurate identification of the most important delay factors.

Table 4.10: Number of construction projects that respondents had participated in

Country	Minimum	Maximum	Total
Libya	4	788	788
UK	3	267	267

Table 4.10 demonstrates how professional's with different levels of experience contributed to this survey. The participants' experience regarding the number of projects in which they have been involved ranges from 4 to 788 projects in Libya and 3 to 267 in the UK. Since the number of projects that a respondent has participated in has a high impact when analysing delay impacts and factors, ensuring that a breadth of experience was represented within the sample improves the reliability of the survey results.

4.6.4 Delays experienced

Table 4.11 and Figure 4.13 indicate that the vast majority of contractor and consultant respondents had experienced delays in a construction project. 47 out of 76 participants – or nearly (61.84%) – had been involved in projects that were not completed as planned or as stated in the contract, whereas just 29 (38.16%) participants had no experience of delay.

Table 4.11: Experience of construction project delays among contractors and consultants

Description	Country	Yes	No	Total	%
Experienced delay	Libya	42	2	44	57.90%
	UK	5	27	32	42.10%
Total		47	29	76	100%

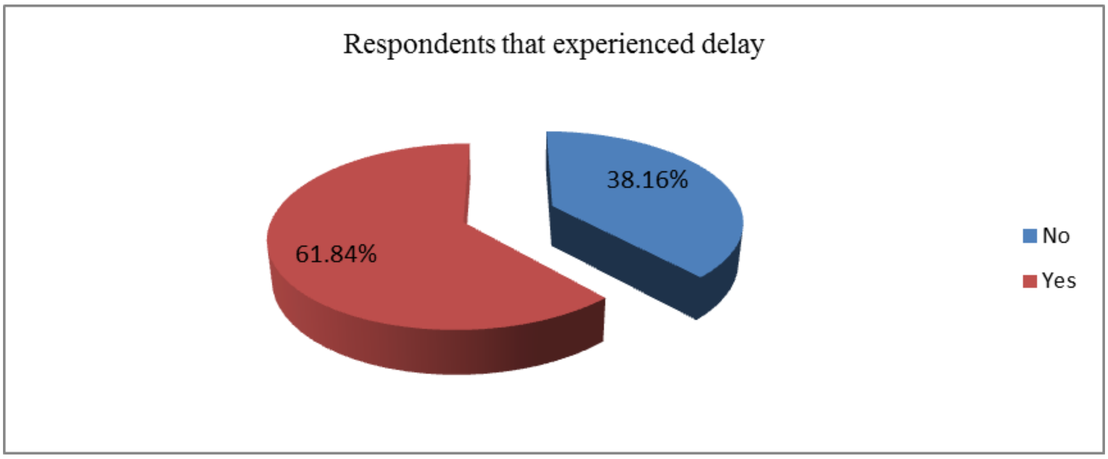


Figure 4.13: Percentages of respondents who had experience delays

4.6.5 Ratio of delayed to non-delayed projects

Table 4.12 shows that 640 projects out of 1,055 were delayed. Conversely, 415 projects were successfully delivered as scheduled. The number of delayed projects forms 60.66% of the total projects, which is 543 out of 788 from Libya and 97 out of 267 from the UK.

Table 4.12: Ratio of delayed to non-delay projects

Country	No of project	Delayed project	None delayed project	% of delayed project
Libya	788	543	245	68.90%
UK	267	97	170	36.32%
Total	1055	640	415	60.66%

The most notable point is the big difference in the delayed ratio between Libya and the UK, which can be seen clearly in Figures 4.14 and 4.15. The percentage of delayed projects in Libya was 68.90%, whereas 31.10% were not delayed. In the UK, however, only 36.32% of projects were delayed, compared to 63.68% that were not.

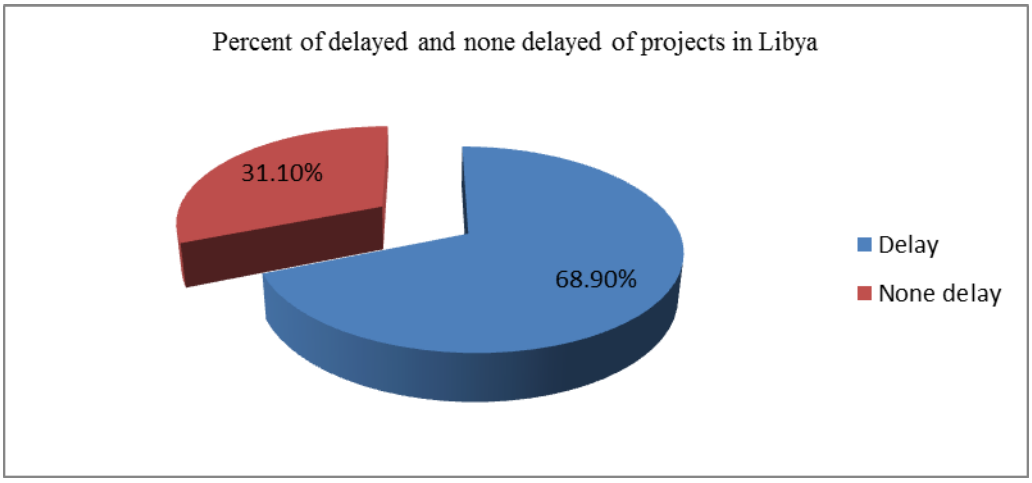


Figure 4.14: Percentage of delayed and non-delayed projects in Libya

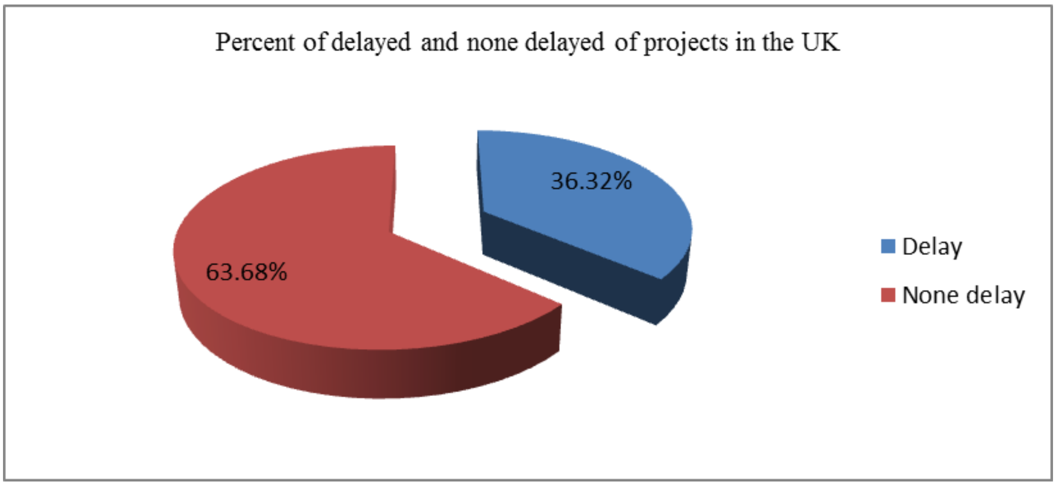


Figure 4.15: Percentage of delayed and non-delayed projects in the UK

This contrast may be the result of differences in knowledge, experience and resources, as the UK is a developed country, whereas Libya is still classified today, in the CI

World Fact Book (2004), as a developing country, although major developments have taken place in recent decades.

4.6.6 Percentage of delayed time of the delayed projects

The percentage of delayed time was classified into five categories, and respondents were asked to select more than one of these categories to indicate the percentage delayed time of the delayed projects that they had participated in. Table 4.13 shows that the percentage delayed time of delayed projects for nearly two-fifths of respondents (28; 36.84%) was from 31% to 50% of the project plan. Projects that had been delayed by 10% to 30 % of the project plan time were second, cited by 25 respondents (32.90%). The percentage of respondents who had experienced a percentage delay less than 10% was 17.12% (13), while 9 respondents (11.84%) had experienced from 51% to 100% delay time. The lowest frequency was for a percentage delay of over 100% of the project schedule, which only one respondent (1.32%) had been involved in.

Table 4.13: Percentage delayed time of construction projects

Percentage of delayed time	Country				Total	Percent
	Libya		UK			
	No	%	No	%		
< 10 %	4	9.2%	9	23.13%	13	17.12%
10 – 30 %	11	25.31%	14	43.75%	25	32.90%
31 – 50 %	21	47.28%	7	21.88%	28	36.84%
51 – 100%	7	15.95%	2	6.25%	9	11.84%
> 100%	1	2.28%	0	0	1	1.32%
Total	44	100	32	100	76	100

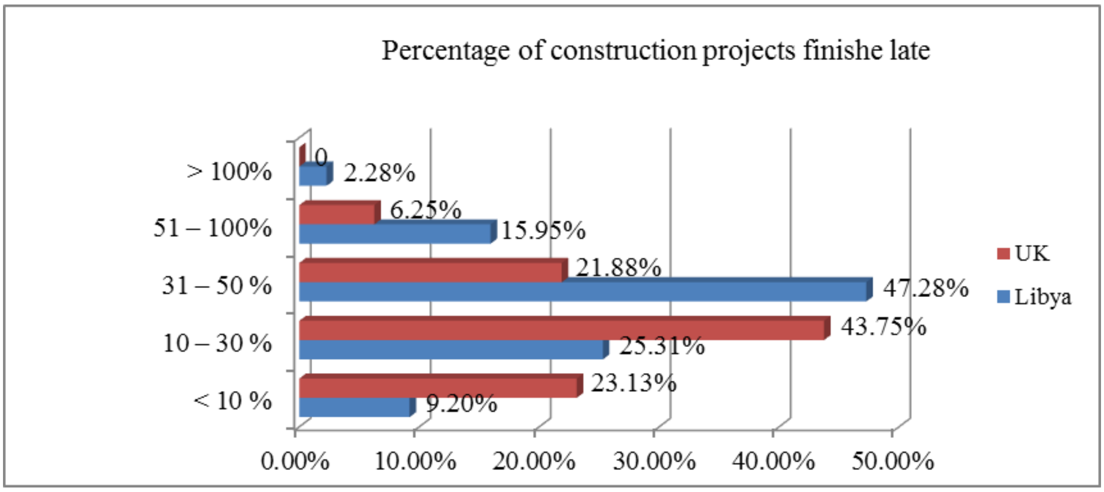


Figure 4.16: present of delayed construction projects in both countries

Figure 4.16 illustrates the percentage of respondents, by country, who specified each average delay time. It shows that nearly half of the Libyan respondents (47.28%) experienced an average delay of 31-50%, whereas most UK respondents who had been involved in delayed projects experienced an average delay time of 10-30% of the project plan. The average delay times across both countries are shown in Figure 4.17 below.

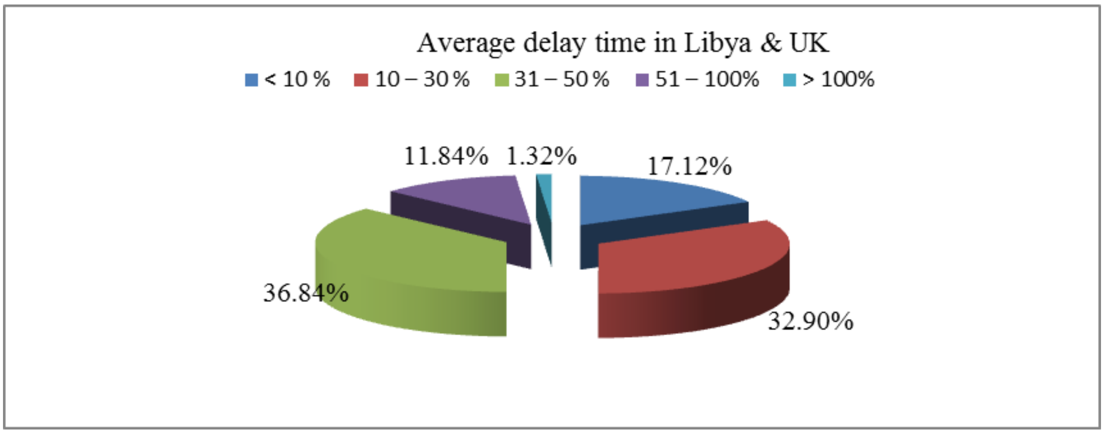


Figure 4.17: Average delay time in Libya and the UK

4.6.7 Average of authorised delayed time

The delay time of a project may be allowed by the owner or it may not. That usually depends on the type of delay, contract specification, and characteristics of the owner. The durations of authorised time were divided into four categories, which include all probabilities that may occur in a delayed project.

Table 4.14: Average of delayed time authorised by the owner

Average of authorised delayed time	country				Total
	Libya		UK		
	No	%	No	%	
- About 75% of delayed time	3	6.82%	2	6.25%	5
- About 50% of delayed time	7	15.90%	2	6.25%	9
- About 25% of delayed time	19	43.18%	10	31.25%	29
- The contractor paid the liquidated damages for all delayed time	15	34.10%	18	65.25%	33
Total	44		32		76

Table 4.14 shows that 33 respondents reported that the average delay time was not authorised by the owner, and that the contractor paid liquidated damages for all delayed time. Among those respondents who reported that delay time had been authorised, 29 approximated it to an average of about 25% of delayed time, 9 to about 50% of delayed time, and 5 to about 75% of delayed time.

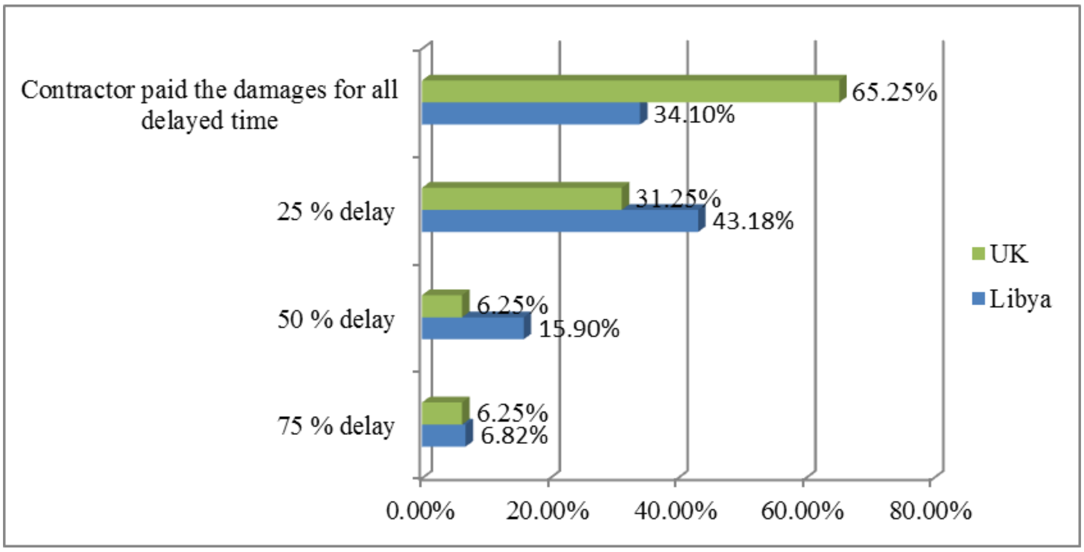


Figure 4.18: Present of average authorised time of delayed projects in both countries

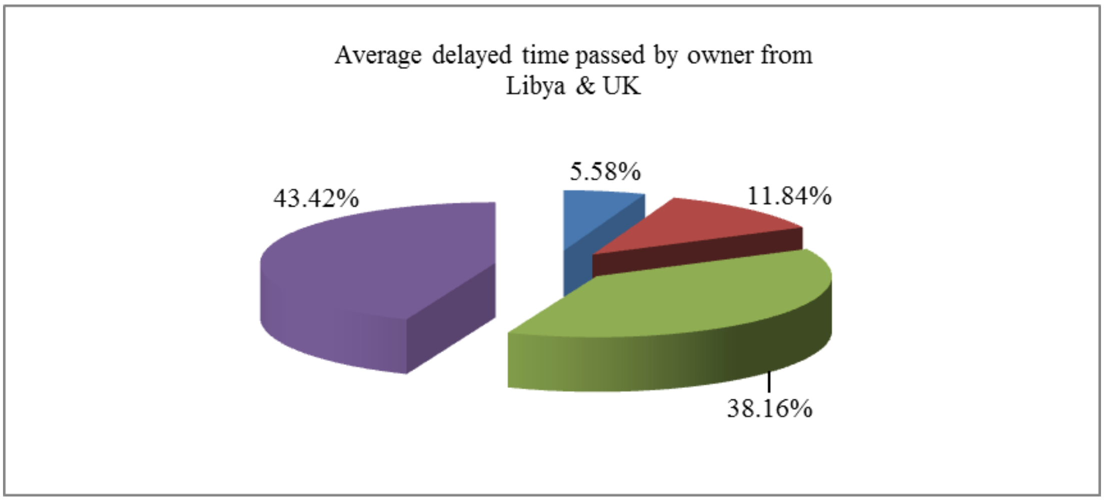


Figure 4.19: Average delayed time passed by the owner from Libya & UK

Figure 4.18 shows the averages of authorised time of delayed projects in Libya and the UK. The chart shows that 34.10% of Libyan respondents experienced delayed projects with, on average, no authorisation for any liquidated damages, while 65.25% of UK respondents experienced that. At the same time, the average of both countries, shown in Figure 4.19, indicates that the majority of owners in Libya and the UK do not authorise all delayed time.

4.6.8 Responsible party for delays

Table 4.15: Responsible party for delays based on all respondents' opinions

Responsible for delays	Country				Total	%
	Libya	%	UK	%		
Contractor	16	22.22%	11	25%	27	23.28%
Consultant	33	45.83%	14	31.82%	47	41.52%
Owner	23	31.95%	19	43.18%	42	36.20%
Total	72	100%	44	100%	116	100%

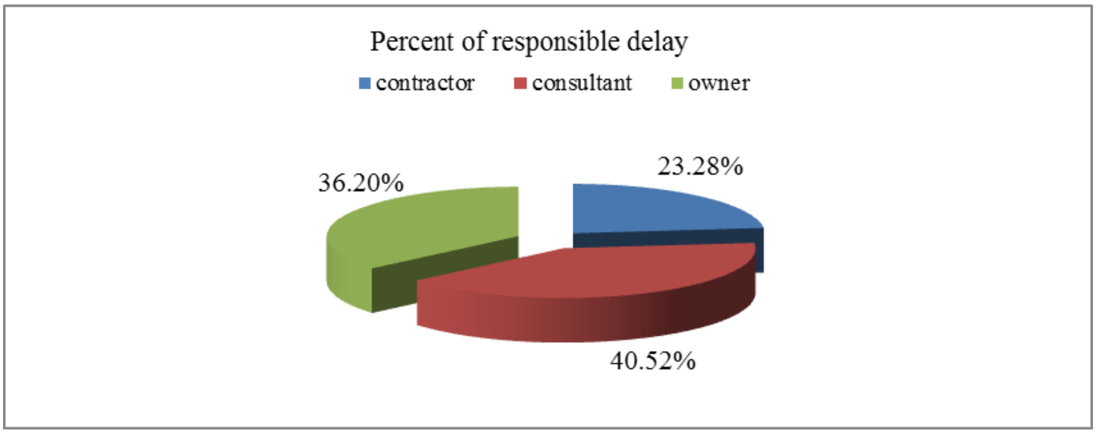


Figure 4.20: Delay responsibility based on all respondents' opinion

The respondents, including contractors, consultants and owners in both countries, identified that the consultant was the most responsible party for construction projects' delays (Table 4.15 and Figure 4.20).

Respondents considered that consultants were the category most responsible for delays in Libyan construction projects (45.83%), with 47 respondents across both countries (41.52%) citing this group. In the UK, in contrast, owners (43.18%) were most commonly named as being the party most responsible for delays. Contractors emerged as the least responsible party for delays across Libya and the UK, being named by 27 respondents (23.28%). However, it should be remembered that these are the results of all the respondents, and more subtle points can be discovered in the next part of the chapter as it breaks down the results according to group opinions.

4.7 Section three: delay factors analysis

A total seventy-five well-recognised delay factors were identified through the earlier review of literature related to construction delays (Chapter 2). With the aim of ranking them, the identified delay factors were included in the questionnaire (Assaf and Al-Hejji, 2006). The main objective of this survey was to determine the importance level of all delay factors in construction projects, given that each delay factor has a different level of impact on project delays according to its nature and complexity. Therefore, the Importance Weight (IW) of each critical delay factor has been considered as a main input in the simulation model of the delay analysis system, introduced in this study.

The aim of this section is to rank the level of frequency and severity of each delay factor using the range of weights provided. All delay factors were ranked into different professional groups (contractors, consultants, owners) in both countries (Libya and the UK respectively). Moreover, three ways of ranking were used: all causes rank, subcategories rank, and main categories rank. The analysis and discussion of ranking depends on the importance of delay factors rather than ranking them based on frequency and severity separately. The details of the calculation to determine the value of IW of a delay factor are illustrated and presented in Appendix-B1. Similarly, the IW of all delay factors identified from the survey was calculated using the formula shown in section 4.3, and presented in Appendix-B1, which is used to rank the delay factors. The discussion of comparison of delay factors found in both Libya and the UK construction industry is presented in next section

4.7.1 Comparison of delay factors

Considering the contractors' points of view, the industry survey revealed that the top five delay factors in the Libyan construction industry were low-skilled manpower, changes in the scope of the project, delays in materials delivery, shortages of required equipment, and changes in materials prices. However, the rise in the prices of materials, poor control of subcontractors by the contractor, poor economic conditions, poor communication between the contractor and involved parties, and delays in the preparation of contractor documents were found to be the top five delay factors in the UK construction industry.

When considering the owners' points of view, the industry survey found that the top five delay factors in the Libyan construction industry were changes in materials prices, delays in issuing change orders, delays in furnishing and delivering the site to the contractor by the owner, and modifications (replacement and addition of new work to the project, change in specifications). In contrast, the top five delay factors in the UK construction industry in order of importance were delays in the settlement of contractors' claims by the owner, financial problems (delayed payments, financial difficulties and economic problems), unrealistic contract durations, slow decision-making by the owner organisation, and interference by the owner in the construction operations.

Furthermore, after considering the consultants' points of view, the survey results showed that the top five delay factors in the Libyan construction industry were delayed and slow supervision in making decisions, delays in the preparation of drawings, delays in the approval of contractor submissions by the consultant, slowness in giving instructions, and the poor qualifications of consultant engineering staff assigned to the project. In the case of the UK construction industry, the top five delay factors in order of importance were found to be poor communication between the consultant engineer and other parties, poor qualifications of the consultant's technical staff assigned to the project, and difficulties in financing the project by the contractor. The importance value of all delay factors (from the three aspects of contractor, owner and consultant) and their ranks in terms of importance level within the frequency and severity scale

4.7.2 Analysis of delay factors - categories and individuals

The delay factors associated with the construction projects were grouped into four main categories: those related to contractors, consultants, the owner's performance, and others. Delay factors were ranked based on the Average Weight (AW). This determined a basis for calculation of the Importance Index (II) of all delay factors that came under this category. However, analysing the AW method of a specific category is useful for determining the average importance weight of that category (Assaf and Al-Hejji, 2006). The contractor performance category includes 35 individual delay factors, while the consultant category includes 10, the owner category 14, and the others category 16 delay. In this survey, the Important Index (II) identified by Aibinu et al (2002) is used to analyse the survey data and to rank the delay factors, which are presented below.

The (AW) is the importance index of the delay factors category, which is the average importance weight without considering the effect on the number of delay factors; however, its rank does not convey the entire importance. The AW creates an awareness of the average importance level of the delay factors under the related category, and compares them. In contrast, the Importance Index (II) means the importance index of the category with consideration of the number of delay factors in the category, which helps to realise the entire importance of the category among the other categories.

II = AW * M.. (4)

AW= Average weight of delay factors
AW = IW/R
IW = Importance Weight
R = Number of respondents
M = Number of category delay factors / total number of all delay factors (75)

4.7.3 Survey Data Analysis

The results of the industry survey in the ranking scale of Importance Index (II) and Average Weight (AW) are presented in Tables 4.16, 4.17, 4.18 and 4.19 for all categories in both countries (UK and Libya). From the analysis of the survey data, it is found that the delay factors associated with consultants in Libya are higher in the ranking scale of the Importance Index (II) than the delay factors associated with the contractor, owner or other delay factors. There are many delay factors in the contractor category, but these have a lower Important Index (value) than the delay factors related to the consultant and owner categories in Libya. This resulted from the existence of many non-important delay factors in the contractor sub-category. The detailed discussions of the main and sub-categories are presented below.

Table 4.16: Average Weight (AW) of sub-categories by country's respondents

Ctg	**Libya**				**UK**				**Average**			
	IW	**R**	**AW**	**Rank**	**IW**	**R**	**AW**	**Rank**	**IW**	**R**	**AW**	**Rank**
C/MP	395.46	144	2.746	**2**	111.94	88	1.272	**6**	507.40	232	2.187	**6**
C/EQ	534.05	288	1.854	**7**	160.86	176	0.913	**8**	694.91	464	1.497	**8**
C/MT	688.08	288	2.389	**4**	352.56	176	2.003	**3**	1040.64	464	2.247	**5**
C/PM	957.02	600	1.595	**8**	592.10	286	2.070	**2**	1549.12	886	1.748	**7**
OWN	881.38	392	2.248	**5**	403.53	168	2.401	**1**	1284.91	560	2.294	**4**
CNS	941.39	280	3.362	**1**	193.29	190	1.017	**7**	1134.68	470	2.414	**2**
EP	598.71	280	2.138	**6**	387.38	140	1.910	**4**	986.09	420	2.347	**3**
EF	1372.28	508	2.701	**3**	508.55	268	1.897	**5**	1880.83	776	2.423	**1**

Table 4.17: Importance Index (II) of sub-categories by country's respondents

Ctg	Libya				UK			Average		
	M	AW	II	RNK	AW	II	RNK	AW	II	RNK
C/MP	0.080	2.746	0.220	**8**	1.272	0.102	**8**	2.187	0.175	**8**
C/EQ	0.160	1.854	0.297	**6**	1.913	0.146	**6**	1.497	0.240	**7**
C/MT	0.160	2.389	0.382	**5**	2.003	0.321	**4**	2.247	0.360	**4**
C/PM	0.307	1.595	0.490	**2**	2.070	0.636	**2**	1.748	0.537	**2**
OWN	0.187	2.248	0.420	**4**	2.401	0.449	**3**	2.294	0.429	**3**
CNS	0.133	3.362	0.447	**3**	1.017	0.135	**7**	2.414	0.321	**5**
EP	0.133	2.138	0.284	**7**	1.910	0.254	**5**	2.347	0.312	**6**
EF	0.400	2.701	1.081	**1**	1.897	0.759	**1**	2.423	0.970	**1**

II: importance index, M: modulus of the number of causes in the delay category, MP: manpower, EQ: equipment, MT: material, PM: project management, EP: early planning and design, EF: external factor

Table 4.18: Average Weight (AW) of main categories by country's respondents

Ctg	Libya				UK				Average			
	IW	R	AW	RNK	IW	R	AW	RNK	IW	R	AW	RNK
C	2574.61	1320	1.950	**4**	1217.46	726	1.677	**3**	3792.07	2046	1.853	**4**
OWN	881.38	392	2.248	**3**	403.53	168	2.402	**1**	1284.91	560	2.294	**3**
CNS	941.39	280	3.362	**1**	193.29	190	1.017	**4**	1134.68	470	2.414	**1**
Other	1970.99	788	2.501	**2**	895.93	408	2.196	**2**	2866.9	1196	2.397	**2**

Ctg: category, IW: importance weight, R: respondents, AW: average weight, C: contractor, OWN: owner, CNS: consultant, other includes EP and EF

Table 4.19: Importance Index (II) of main categories by country's respondents

Ctg	Libya				UK			Average		
	M	A W	II	RNK	A W	II	RNK	A W	II	RNK
CON	0.177	2.146	0.393	**4**	1.565	0.276	**3**	3.711	0.656	**3**
OWN	0.187	2.248	0.420	**3**	2.402	0.449	**1**	4.650	0.869	**1**
CNS	0.133	3.621	0.628	**1**	1.017	0.135	**4**	4.638	0.616	**4**
Other	0.198	2.419	0.418	**2**	1.904	0.338	**2**	4.323	0.769	**2**

4.7.3.1 Contractor delay factors

In this category, the identified delay factors related to contractors were analysed. These factors were subdivided into four groups: materials, equipment, manpower, and project management. Tables 4.17 and 4.19 present the results between both countries on the Importance Index (II) scale. In Libya, the survey results show that the contractor was ranked as the fourth most responsible party, whereas in the UK, the survey results show that the contractor was ranked third. Table 4.18 shows that the contractor was ranked as the fourth and third most responsible party in Libya and the UK respectively on the scale of Average Weight (AW).

The outcome of this exercise helps public organisations (government departments) and private owners to identify the responsible parties and to make decisions during the procurement and delay analysis stages regarding the allocation of costs to the respective parties, considering contractors' viewpoints. This also helps to transfer the delay risk, including time and cost implications, to the responsible party from contractor aspects.

Materials

According to the scale of Importance Index (II) in material subcategories, delay factors due to materials were ranked at fifth in Libya, but fourth in the UK, as shown in Table 4.17. Therefore, Libyan construction projects suffer more delays than UK because of materials-related factors. These factors include changes in materials prices, delays in materials delivery, changes in materials specifications, and a shortage of required materials. However, on the scale of Average Weight (AW), delay factors related to materials sub-categories were ranked at fourth in Libya and third in the UK (Table 4.16).

Equipment

Delays due to equipment were found at sixth rank position in both countries according to the scale of Importance Index (II). The details of ranking for the equipment sub-categories are presented in Table 4.17. However, the delay due to equipment sub-categories was at seventh rank in Libya and eighth rank in the UK based on the Average Weight (AW) (see Table 4.16). The survey results found that shortages of required equipment, breakdowns of equipment, shortages of skilled operators for excavations, and inadequate equipment used for the works were the key delay factors in the equipment sub-category.

Manpower

Based on the scale of Importance Index (II), the manpower sub-categories of delay factors were ranked at eighth position in both countries (Libya and UK), as shown in Table 4.17. However, the delay due to the manpower sub-categories was at seventh and eighth rank respectively in Libya and UK according to the Average Weight scale, as shown in Table 4.16. The survey results also identified that the delays due to manpower were due to low skills and a shortage of manpower. The shortage of unskilled workers does not act as a major barrier in construction projects as there are sufficient foreigners' labourers; however, most of those workers have low skills.

Project management

Taking into account the scale of Importance Index (II), the project management sub-categories were ranked in second position in both countries (Libya and UK), as shown in Table 4.17, but were ranked eighth and second in Libya and UK respectively according to Average Weight (AW) (see Table 4.16). The survey results exposed how delay factors such as poor site management, the contractor's lack of skills, rework due to faults in construction, and delays in the preparation of contractor document submissions were related to the project management categories in Libyan constriction projects. However, delays in sub-contractor work, contractor's poor coordination with the parties involved in the project, and difficulties in financing the project were causes of delay in this sub-category in the case of UK constriction projects.

4.7.3.2 Consultant delay factors

Based on the Importance Index (II) scale, the consultant delay category in Libya was found to be the most important factor in project delays. The survey results also confirmed that consultants were ranked as the most responsible (first ranked) party for the delay in construction projects in Libya, but ranked as fourth for delay in construction projects in the UK (see Table 4.19). On the scale of the Average Weight (AW), consultants were ranked in first and fourth position in Libya and the UK respectively, as shown in Table 4.18. The causes of delay related to consultants were delays in the preparation of drawings, delays in the approval of contractor submissions, slowness in supervision and making decisions, a lack of consultancy staff, slowness in giving instruction, and poorly qualified consultant engineer's staff being assigned to the project.

The outcome of this exercise helps public organisations (government departments) and private owners to identify the responsible parties and to make decisions during the procurement and delay analysis stages regarding the allocation of costs to the respective parties, considering the consultant's viewpoints. This also helps to transfer the delay risk, including time and cost implication, to the responsible party from consultant aspects.

4.7.3.3 Owner delay factors

According to the scale of the Importance Index (II), delay factors related to the owner category were ranked third in Libya and first in the UK, as shown in Table 4.19. Similarly, the owner category was also ranked at third and first position on the scale of Average Weight (see Table 4.18). The delay factors related to the owner's categories were delays in payment, a lack of sufficient financial support, delays in providing the construction site to the contractor, delays in issuing change orders, a lack of working knowledge, an improper project feasibility study, and ordering additional works to the project and amending contract specifications.

The outcome of this exercise helps public organisations (government departments) and private owners to identify the responsible parties and to make decisions during the procurement and delay analysis stages regarding the allocation of costs to the respective parties, considering the owner's viewpoints. This also helps to transfer the delay risk, including time and cost implication, to the responsible party from owner aspects.

4.7.3.4 Other factors

This category contains delay factors that are not related to the three parties (contractor, consultant and owner) during the construction stage. It comprises two subcategories: early planning and design, and external factors. This delay category held second position in both countries (Libya and UK) on the scale of the Importance Index (II), as shown in Table 4.19. Also, this category ranked in second positions in both countries in terms of Average Weight, as shown in table 4.18.

Early planning and design

The early planning and design delay subcategory includes poor early planning that leads to a change in the scope of projects; these problems occurred more often in construction projects in Libya than in the UK. Considering the Importance Index (II) scale, the early planning and design delay category was ranked as the seventh most important subcategory in Libya, whereas it was found at fifth rank in the UK, as shown in Table 4.17. However, these subcategories ranked sixth and fourth in Libya and the UK respectively based on the Average Weight (AW) scale (see Table 4.16). The survey results identified that the delays related to the early planning and design categories were due to poor early planning that leads to changes in the scope of the projects, and because of ambiguities, mistakes and inconsistencies in specifications and drawings.

External factors

According to the scale of the Importance Index (II), the external factors sub-category of delay factors was ranked in first positions in both countries (Libya and UK), as shown in Table 4.17. However, according to the Average Weight (AW) scale, the external factors sub-categories were ranked third and fifth respectively in Libya and the UK (see Table 4.16). The survey results identified that delays related to the external factors categories were due to rises in the prices of materials, delays in agreeing design drawings and confirming tested materials, public organisations' utility works, a shortage of required equipment on the local market, and economic crises, including devaluation of currency and price inflation of materials.

4.8 Statistical tests

Statistical tests are one of the analytical methodologies that are widely used to analyse survey data in academic and industry research projects. The statistical tests focus on analysing the confidence level of the survey data and discussing the results obtained from the statistical tests. The SPSS program was used to test the survey data. Different types of statistical tests are available to test and analyse the delay factors; the T-Test (one sample T-Test, pair sample T-Test) and Wilcoxon rank test were selected to identify the relationship and confidence level of the survey data.

4.8.1 T-tests

A T-test is used to determine whether there is a significant difference between two sets of scores. There are two main types of T-test in statistical data analysis: pair sample t-test and one-sample t-test (Nelson, 2004).

The pair sample t-test is selected to compare the means of two variables or groups. The t-value, df and two-tail significance can determine whether the groups come from the same or different population groups. However, significance value can also be determined by looking at the probability level (p) specified under the heading two-tail significance. If the probability value is less than the specified alpha value, then the observed t-value is significant. The 95 per cent confidence interval indicates that 95% of the time the interval specified contains the true difference between the population means.

In this study, a pair sample T-test was used to analyse the survey data under three categories (owner, contractor and consultant, for both the UK and Libya in frequency and severity scales) and to compare the significance and reliability of pair samples (between frequency and severity scales for both the UK and Libya). The survey results of the pair sample t-test (presented in Appendix-B2 from Tables 1, 3 and 5) show that a significant difference exists between the three categories (contractors, owner and consultants) in Libya and the UK in terms of the frequency and severity scale. The views of the respondents from all three categories in the UK and Libya confirm the significance regarding the delay factors.

One-Sample t-test: Reasons to select a one-sample t-test are:

1- To compare a sample distribution with a hypothetical distribution, such as the normal.
2- To make inferences about the parameters of a single population from the statistics of a sample, for the purpose of estimating the parameters of an unknown population.
3- To compare the set of scores in the sample to a normally distributed set of scores with the same mean and standard deviation. If the test is non-significant ($p > 0.05$), then it confirms that the distribution of the sample is not significantly different from a normal distribution (it is probably normal). However, if the test is significant ($p < 0.05$) then the distribution in question is significantly different from a normal distribution (Nelson, 2004).

In this study, a one sample T-test was used to analyse the survey data under three categories (owner, contractor and consultant) for both the UK and Libya in frequency and severity scales) and to identify the significance and reliability of data. The survey outputs of the one sample t-test (presented in Appendix-B2 from Tables 2, 4 and 6) revealed that the causes of delay cited by Libyan and UK respondents from all three categories have significance in terms of frequency and severity scales separately.

4.8.2 WILCOXON – rank test:

The Wilcoxon test is performed in a situation where two sets of scores need to be compared; however, these two sets of scores should come from the same subjects (Nelson, 2004). In the study, a Wilcoxon test was used to analyse all three categories in both the UK and Libyan delay factors.

In the case of owners, information on ranked scores is shown in Table 9 of Appendix-B2. Negative rank numbers show that the UK owner score is less than the Libyan owner scores whereas positive rank numbers indicate that UK owner scores are more than Libyan owner scores in terms of frequency. Similarly, in case of the severity score, negative rank numbers indicate that the Libyan owner score is less than the UK owner score whereas positive rank numbers indicate that the Libyan owner scores are more than the UK owner scores. For more details see Appendix-B2).

Looking at Libyan and UK consultants, the results of the ranked scores presented in Table 7 of Appendix-B2 show that the UK consultant score is less than the Libyan consultant score, whereas positive rank numbers indicate that the UK consultant scores are more frequent than the Libyan consultant scores. Similarly, in the case of the severity score, negative rank numbers indicate that the UK consultant score is less than the Libyan consultant score, whereas positive rank numbers indicate that the UK consultant scores are more than Libyan consultant scores. However, there are no numbers with tied scores (i.e. that are the same) between the UK and Libyan consultants. For more details see Appendix-B2.

Whereas in case of contractor, the results of ranked scores in negative ranks number (presented in table 11 of appendix-B2) confirms that UK contractor score is less (negative) than Libyan contractors score whereas positive ranks number indicates that UK contractor scores is more (positive) than Libyan contractors scores in case of frequencies. Similarly, in case of severity scale, the negative ranks number indicates that UK contractor score is less (negative) than Libyan contractor score whereas positive ranks number indicates that UK contractor scores is more (positive) than Libyan contractor scores. For more details (see appendix-B2)

The statistical tests (stated above) confirm that the survey data are significant. The significance value of the survey data indicates that there is a probability of delay in construction projects due to several delay factors, which were identified through the industry survey. The relative importance of each of the frequency and severity scales of delay factors perceived by the respondents were tested at 95% of confidence level. The P-values for both scale of frequency and severity for all three groups, such as owners, consultants and contractors, were found to be less than 0.05 in both Libya and the UK. Therefore, it is concluded that the survey results are significant. The results showed that assumptions made in this study related to the delay factors in construction projects, and tested by different statistical tests, are significant and valid.

4.9 Chapter summary

This chapter discussed the questionnaire survey, data analyses and discussion of the survey results. In summary:

- The survey results showed that consultants were the most responsible party for the delays in construction projects in Libya, whereas owners were the most responsible party for the delays in the UK.

- The survey results also found that the rank level of delay factors was different in relation to the three parties (contractor, consultant and owner) in both countries.

- Considering the contractor’s point of view, the survey result showed that there were five most critical delay factors among the all identified factors in the Libyan construction industry. These critical delay factors were changes in materials prices, delays in materials delivery, shortages of required equipment, low-skilled manpower, and changes in the scope of the project. In the UK construction industry, rises in the prices of materials, poor control of subcontractors by the contractor, poor economic conditions (currency, inflation rate, etc.), poor communication between the contractor and the parties involved in the project, and delays in the preparation of contractor document submissions were the most critical delay factors.

- Considering the owner's point of view, the survey results found that slow decision-making by the owner's organisation, changes in materials prices, delays in issuing change orders, delays in furnishing and delivering the site to the contractor, and modifications (i.e. the addition of new work to the project and changes in specifications) were the five most critical delay factors in Libya. However, the delay in the settlement of contractor claims by the owner, financial problems (delayed payments, financial difficulties and economic problems), unrealistic contract duration, and interference by the owner in the construction operations were the most critical delay factors found in the UK construction industry.

- From the consultant's point of view, the survey results identified that slow supervision and delays in making decisions, delays in the preparation of drawings, delay in the approval of contractor submissions by the consultant, slowness in giving instruction, and poor qualifications of consultant engineers' staff assigned to the project were the five most critical delay factors in the Libyan construction industry. However, poor communication between the consultant engineer and other parties, and difficulties in financing the project by the contractor were most critical delay factors found in the UK construction industry.

- Identifying the responsible party will be expected to assist owners/clients in their decision-making process during the procurement of a public and private construction project.

- The Importance Weight of delay factors was found to be different from the viewpoints of contractors, owners and consultants in both the UK and Libya.

- The IW of delay factors identified from all parties was used as a key input into the delay analysis system for analysing and quantifying the impact of delay factors associated with construction projects from both countries.

The next chapter discusses the conceptual framework of the delay analysis system, which was introduced in the research study.

Chapter 5-

Conceptual Framework of Delay Analysis System (DAS)

Chapter 5: Conceptual Framework of DAS

5.1 Introduction

This chapter discusses a conceptual framework of a Delay Analysis System (DAS) with a simulation model, which is introduced in this study. The framework was designed under three parts: input, process and output. The list of critical delay factors, Importance Weight (IW) of each critical delay factor, and the list of the critical activities of a project are considered as the main inputs of the system. The process of the system was divided into four sub-sections: identification of influence value of each delay factor; selection of the delay factors affecting each critical activity; generation of a random number based on the selected type of risk distribution; and integration of the critical delay factors with critical activities of a project. This chapter also explains the methods and equations integrated within the DAS in order to analyse and quantify the impact of delay factors in terms of project duration. In this system, Critical Path Method (CPM) technique is used to identify the critical activities in a construction project. Site information collected through the industry survey has been used to allocate the numbers of delay factors affecting each critical activity. The Monte Carlo Simulation (MCS) technique is used to generate random numbers. The framework of the DAS introduced in this study provides the information on how the critical activities and critical delay factors can be integrated to identify the possible delay in a construction project. The quantification of the possible durations of a particular project is the key output of the system. The next section discusses the design of the conceptual framework of the DAS, which is arranged into inputs, process and outputs.

5.2 Design of a conceptual framework

A conceptual framework of the DAS was designed to analyse the critical delay factors and to quantify the impact of the delay factors in a construction project. The list of the critical delay factors was identified by analysing the collected data from the industry survey (see Chapter 4). Figure 5.1 presents a conceptual framework of the DAS. The framework was divided into three sections: input, process and output.

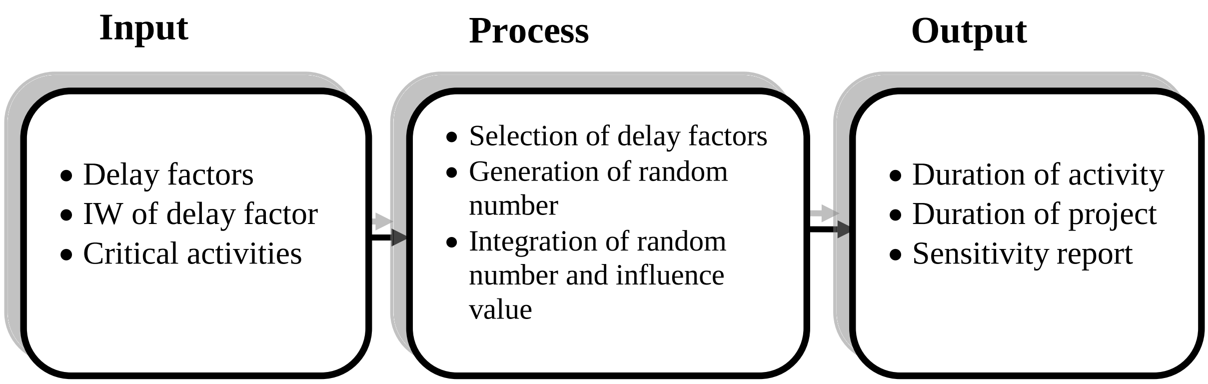


Figure 5.1: Conceptual framework for the project delay analysis system

- **Input:** - the inputs are: the critical delay factors identified from the industry survey; the Importance Weight (IW) of each delay factor; and the critical activities of a construction project.
- **Process:** - This includes the identification of critical delay factors that affect each critical activity of the programme with influence value, determination of the probability of distribution random number, and the integration of the random number with the influence value using the MCS.
- **Output: -** The outputs of the system are the delay of each activity and the total delay in a construction project in terms of duration with sensitivity of the critical delay factors.

The details of inputs, process and outputs of the DAS are discussed in the following sections.

5.3 Inputs of the system

The main inputs of the DAS are the list of critical delay factors; the Importance Weight (IW); and the critical activities of a construction project. The details of the inputs are shown in Figure 5.2. The IW of delay factors is identified by analysing the frequency and severity index method of each delay factor affecting building construction projects. The list of project activities in a building project are analysed using CPM to identify the critical activities. These critical activities have been considered as a key input in the

DAS because they are responsible for the delay of a project and the overrun of the project cost.

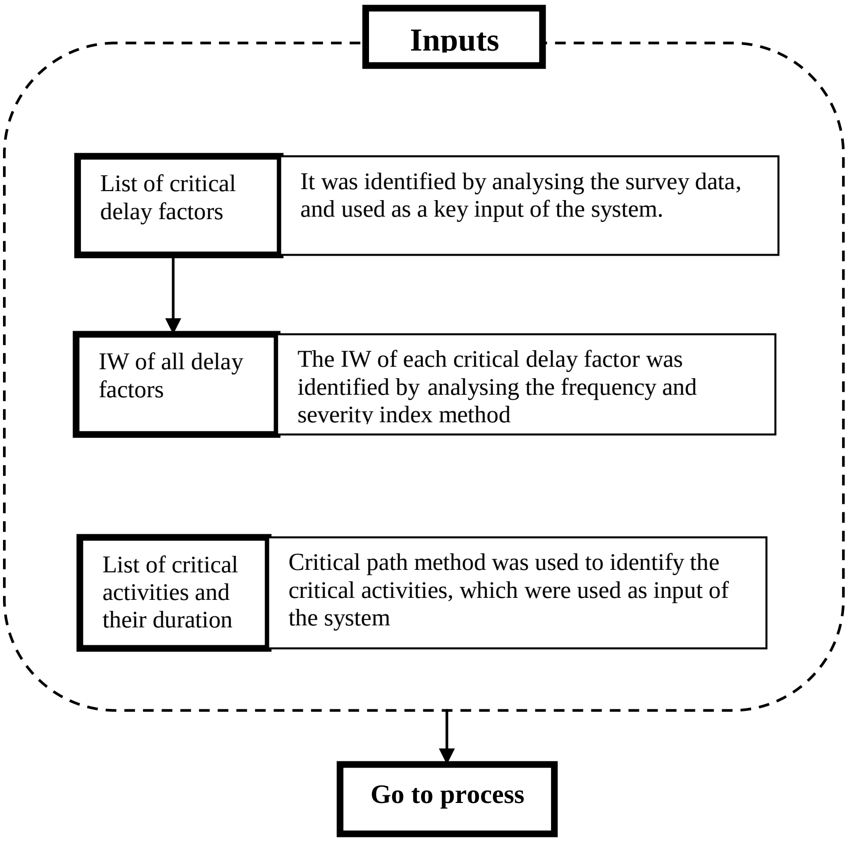


Figure 5.2: Details of the inputs of the DAS

5.3.1 Identification of critical delay factors

The list of critical delay factors is identified by analysing the survey data and ranking them from top to bottom in terms of impact level using frequency and severity index methods (see chapter 4). Different aspects including contractors, consultants, owners and external factors have been considered for ranking the delay factors. After ranking the delay factors, a list of critical delay factors, relevant to a particular project is shortlisted using the knowledge of construction manager during site meeting. The list of these delay factors are used as key input of the system.

5.3.2 Identification Importance Weight

The Importance Weight (IW) of each delay factor will be calculated using the frequency and severity index method. The detailed calculation methods and equations for the calculation of IW are discussed in Chapter 4. A typical list of critical delay factors and their respective IW in a project are presented in Table 5.1.

Table 5.1: A typical list of critical delay factors with different Importance Weights

Causes ID NO	**Typical critical delay factors in a construction project**	**IW**
1	Shortage of required materials	56.60
2	Delay in materials delivery	75.96
3	Changes in materials prices	50.10
4	Low skill of manpower	68.79
5	Delay in sub-contractor work	46.33

5.3.3 Identification of critical activities

A list of project activities with their durations is identified at first from a construction schedule of a project. The existing techniques (for example, CPM) will be used to identify the critical activities of the project, and these critical activities are then considered as an input of the DAS. The CPM is a planning technique, which is normally used for identifying critical activities. The CPM helps to manage the resources of the critical activities in a construction project (Lewis, 2002).

The critical activities of a project are considered in analysing the impact of delays in the DAS because the duration of those critical activities is considered to identify those activities that have a high impact on the overall project delay. In this conceptual model of the DAS, the near-critical activities are not integrated because these activities have less impact compared to the critical activities, even though risk factors are analysed for both critical and near-critical activities. Each activity in the critical path is called a critical activity, since the total float (i.e. slack) of each critical activity is equal to zero. The delay in one activity in the critical path has an impact on the whole project. Therefore, only critical activities are taken into account to analyse the impact from the delay factors in a construction project. In the DAS, critical activities and relevant delay factors were used as key inputs for analysing the impact of the delays in a construction project. The process of the DAS is discussed in the next section.

5.4 Process of the system

The process of the DAS was divided into four sub-sections: selection of the delay factors affecting each critical activity; identification of the influence value of each critical delay factor; identification of risk distribution for generating random numbers; and integration of delay factors with critical activity. These are the main processes of the DAS. The possible duration of each critical activity and the whole project was analysed using the risk simulation model developed by Dawood (1998) to predict the possible duration of activities considering risk factors and the probability of risk distribution. The author believes that the simulation model is suitable for integrating the influence of each risk factor independently, to identify or predict the more reliable duration of project activities by considering the risk factors influencing a project. Recent work by Jaskowski and Biruk (2011) also supports this view.

Jaskowski and Biruk (2011) pointed out that project activities' durations are directly affected by different risk factors independently. Existing risk analysis models failed to provide a more reliable solution for predicting activity and whole project durations, including, for example, simple analytical and neural networks developed by Kog et al. (1999), Chua et al. (1997), Zayed & Halpin (2005), Shi (1999), AbouRizk et al. (2001) and Sonmez & Rowings (1998); the fuzzy set model developed by Lee & Jaskowski, Biruk and Halpin (2003); the Failure Mode and Effects Analysis (FMEA) format to quantify and analyse project risks developed by Thomas and Donald (2003); and the regression model developed by Hanna & Gunduz (2005) and Jaselskis & Ashley (1991), cited in Jaskowski and Biruk (2011). However, Jaskowski and Biruk (2011) agreed that the simulation model developed by Dawood (1998) is a quantitative delay analysis model which considers the impact of each delay factor independently for predicting the duration of activities and the whole project. Therefore, the author believes that the delay factors (risk factors) responsible for construction project delays can be integrated with the delay factors within the simulation model of the delay analysis system to predict the activity or project durations, considering the influence of each risk factor independently.

In the conceptual framework of the DAS, a new method is introduced to predict the impact value of each risk (delay) factor, which is multiplied by a random number to predict the more reliable duration of project activities. The random number is generated using MCS based on the selected types of risk distribution; for example, triangular, uniform, beta, etc. The impact value of each risk is calculated using its Importance Weight (IW), which is derived from the frequency and severity index method (Assaf and Al-Hejji, 2006).

The details of the process, including the MCS technique, are discussed below. Figure 5.3 illustrates the DAS process.

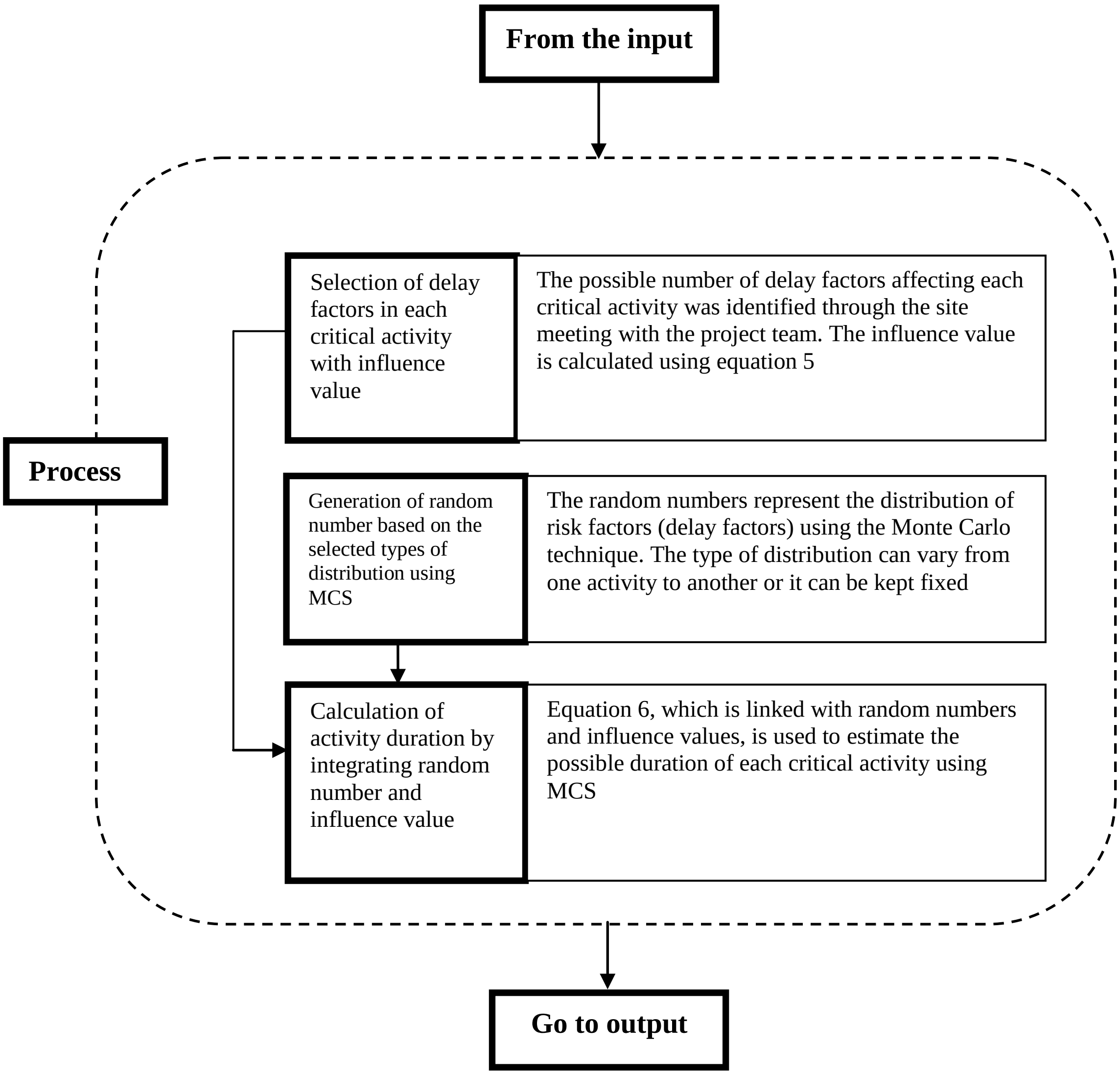


Figure 5.3: Details of the DAS process

5.4.1 Selection of delay factors affecting each critical activity

The possible types and numbers of critical delay factors that affect each critical activity in a project are identified using site information and the knowledge of construction managers that can be collected through a site meeting with project team members. The site meeting needs to be conducted to shortlist the delay factors relevant to a selected project from the check list of delay factors, which can be found from the industry survey. Then, the construction professionals' knowledge is used to select the type and number of critical delay factors affecting each critical activity in the selected project. For example, the typical delay factors relevant to a critical activity are shown in Figure 5.4.

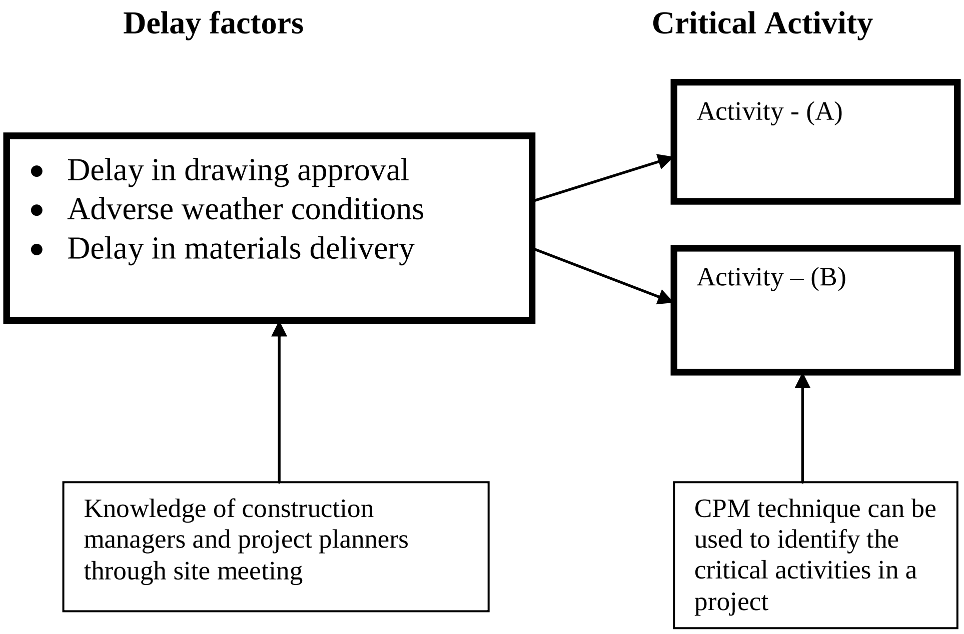


Figure 5.4: Selection of typical delay factors affecting a critical activity

After selecting the possible numbers and type of delay factors, the influence value/coefficient of each delay (risk) factor is calculated using equation 5, which is the ratio of IW of each delay factor to the sum of IW of all delay factors affecting a critical activity. The IW of each delay factor is identified by analysing the survey data, collected through the industry survey. Each activity is affected by different types of risk (delay) factors, where the total influence of all risk factors should be equal to 100% for an activity. Since the risk factors have a high impact on each activity in a construction project and the IW (showing the impact level of each risk factor) is different from project to project or location to location, it is necessary to predict a more reliable duration of each activity, taking into account the value of each risk factor. The IW of each risk factor helps to calculate the more reliable duration of each activity in a project and to analyse the impact of delay factors. Therefore, an equation (shown below) is derived using the weighted ratio.

Equation 5 was developed in this study to calculate the influence value as below.

$$\text{Influence of each delay factor} = \frac{(\text{IW})}{\sum_{1}^{n} \text{IW}} \qquad \text{.. (5)}$$

Whereas,

IW = Importance Weight of each critical delay factor.

IW = FI*SI/100 (Assaf and Al-Hejji, 2006)

FI = Frequency Index

SI = Severity Index

n = Number of delay factors affecting each critical activity.

A typical example is shown below, to calculate the influence value of each delay factors.

Influence value/coefficient of delay (risk) factor number 1

$= \frac{(IW)}{\sum_1^n IW}$ =76.73/ (76.73+65.27+75.96) = 0.35

Similarly, for delay factors number 2 and 3, the calculations using equation 1 and the influence values of delay factors are shown in Table 5.2 below.

Table 5.2: Activities with delay factors, IW, and influence factor values

Critical activity No	C ID NO	The critical delay factors are affected in activities A and B	IW	Influence factors
A and B	1	Waiting time for approval of drawings	76.73	0.35
	2	Severe weather conditions on the job site	65.27	0.30
	3	Delay in materials delivery	75.96	0.35
			217.96	1.00

The knowledge of the construction managers and planners is used to identify the possible delay factors affecting a critical activity and this is considered in order to analyse the impact of delays in a construction project using the DAS. Delays in critical activities and near-critical activities cause the delays in each activity and the whole project. Since critical activities have high impact compared to near-critical activities, the author neglected the near-critical activities and only considered the most critical activities within the DAS. The DAS is expected to assist analysis of the impact of delay factors more accurately, by considering the critical activities and influence value of each delay factor.

5.4.2 Generation of random number

In the DAS, random numbers for each delay factor are generated from the selected type of risk distribution (triangular, uniform, beta, etc). The random numbers are generated between minimum and maximum (0 to 1) using the Monte Carlo simulation technique. The generation of the random number depends on the types of risk distribution.

The behaviour of each risk (delay factors) can be simulated through a distribution function. In risk simulation, the first step is to select the distribution function. Then, the next step is to identify the mean duration for each activity by selecting the pattern or the distribution of the delay (risk) factors throughout the activity duration.

The formula to calculate the mean duration varies according to the types of distribution functions. The distribution type controls the risk occurrence probability since it is different from one project to another. The type of distribution can vary from one activity to another activity; therefore, there are different types of distribution, ranging from uniform, triangular, beta and normal distributions to more complex forms. The usage of the distribution random types was discussed in Chapter 3.

5.4.3 Integration of random number and influence value

The equation developed by Dawood (1998) was used in the DAS to calculate the possible duration of activity considering the impact of delay factors, because the equation helps to quantify the expected project duration, taking into account the impacts of the delay factors affecting each critical activity. The equation also helps to identify or predict the best possible duration of the activity. Therefore, this method was considered for the calculation of the possible duration of a project in this study.

The random numbers and influence values are a multiple factor. This is used to estimate the best possible duration of each critical activity. The possible duration of each critical activity in a project is identified or predicted using equation 6, shown below (Dawood, 1998).

Duration of activity = Min Time + [Max Time – Min Time] x [(RF1 x Random1) + (RF2 x Random2) + (RF3 xRandom3) + (RF n x Random n)...]........................... (6)

Whereas;

Min Time is the minimum that can be assigned to an activity.

Max Time is the maximum that can be assigned to an activity.

Random 1 = random numbers generated by MCS for the selected type of risk distribution

RF n is the influence of the delay factor (n) on a particular activity.

RF n=Influence factor = $\frac{(IW)}{\sum_{1}^{n} IW}$

The minimum and maximum duration of each activity used in the DAS is identified using the site information and the knowledge of the construction manager gained through the site meeting. After identifying the duration of each critical activity, equation 6 is used to identify or predict the best possible duration of the activity, considering the impacts of delay factors affecting each activity in a construction project.

By way of example, the integration of a random number and the influence value of typical critical activities are shown in Table 5.3, below.

Table 5.3: List of critical activity, random numbers and influence values of each delay factor

Activity No	Random 1	Random 2	Random 3	Random 4	Random 5	Rand 1 RF 1	Rand 2 RF 2	Rand 3 RF 3	Ran 4 RF 4	Rand 5 RF 5
						C ID 2	**C ID 64**	**C ID 69**		
A	0.60	0.63	0.50	0	0	0.35	0.30	0.35	0	0
B	0.64	0.60	0.50	0	0	0.35	0.30	0.35	0	0
						C ID 40	**C ID 47**	**C ID 55**	**C ID 58**	
C	0.63	0.63	0.65	0.65	0	0.26	0.24	0.22	0.28	0
						C ID 1	**C ID 2**	**C ID 3**	**C ID 5**	**C ID 45**
D	0.63	0.62	0.61	0.63	0.58	0.18	0.24	0.16	0.14	0.28

5.5 System outputs

The outputs of the DAS are classified into three parts:

- Estimation of delay duration of each critical activity;
- Quantification of possible delay in a construction project;
- Sensitivity report showing major delay factors.

1. *Estimation of delay duration of each critical activity:* this is the first output of the DAS, produced by integrating the influence values of each delay factor affecting the work activity with the risk factor (random number generated by the selected type of risk distribution). Details of formula and discussions are given in section 5.4.3 above. This output provides the possible duration of an activity conceding the influence of delay factors. The possible delay duration of each critical activity (after considering delay factors) is estimated by subtracting the initial duration (duration of activity before considering delay factors) from the total duration of the activity. A typical example of the estimation of activity duration is shown in Figure 5.5 below.

2. *Quantification of possible delay in a construction project*: This is the key output of the DAS, and is calculated through a summation of the possible delay durations of all activities found in the critical path of the project. This provides information on the possible project duration of a construction project taking into account the influence of delay factors found in the project. The quantification of possible delay is identified by subtracting the initial project duration (before considering the impact of delay factors) from the possible project duration (after considering the impact of delay factors) in a construction project. A typical example of the quantification of possible project duration is shown in Figure 5.5 below.

3. *Sensitivity report showing major delay factors:* This is the final output of the DAS. The aim of this output is to provide in-depth information about the level of impact of different delay factors affecting a construction project and to identify sensitivity in project duration due to the variation in the influence value of each delay factor affecting the project. This provides information about how each delay factor is sensible or significant in the case of analysing and taking measures to reduce the

impact of delay factors in the construction project. This is a decision-supporting tool that helps the project manager to understand the gravity of each delay factor and to take proactive measures to control the risk due to those delay factors. A typical example of the sensitivity report of delay factors is shown in Figure 5.5 below.

Finally, it is concluded that the DAS introduced in this study is expected to assist construction managers in analysing the construction resources, and reducing the impact of delay factors in terms of time and quality in a construction project. Figure 5.5 shows the details of the DAS outputs.

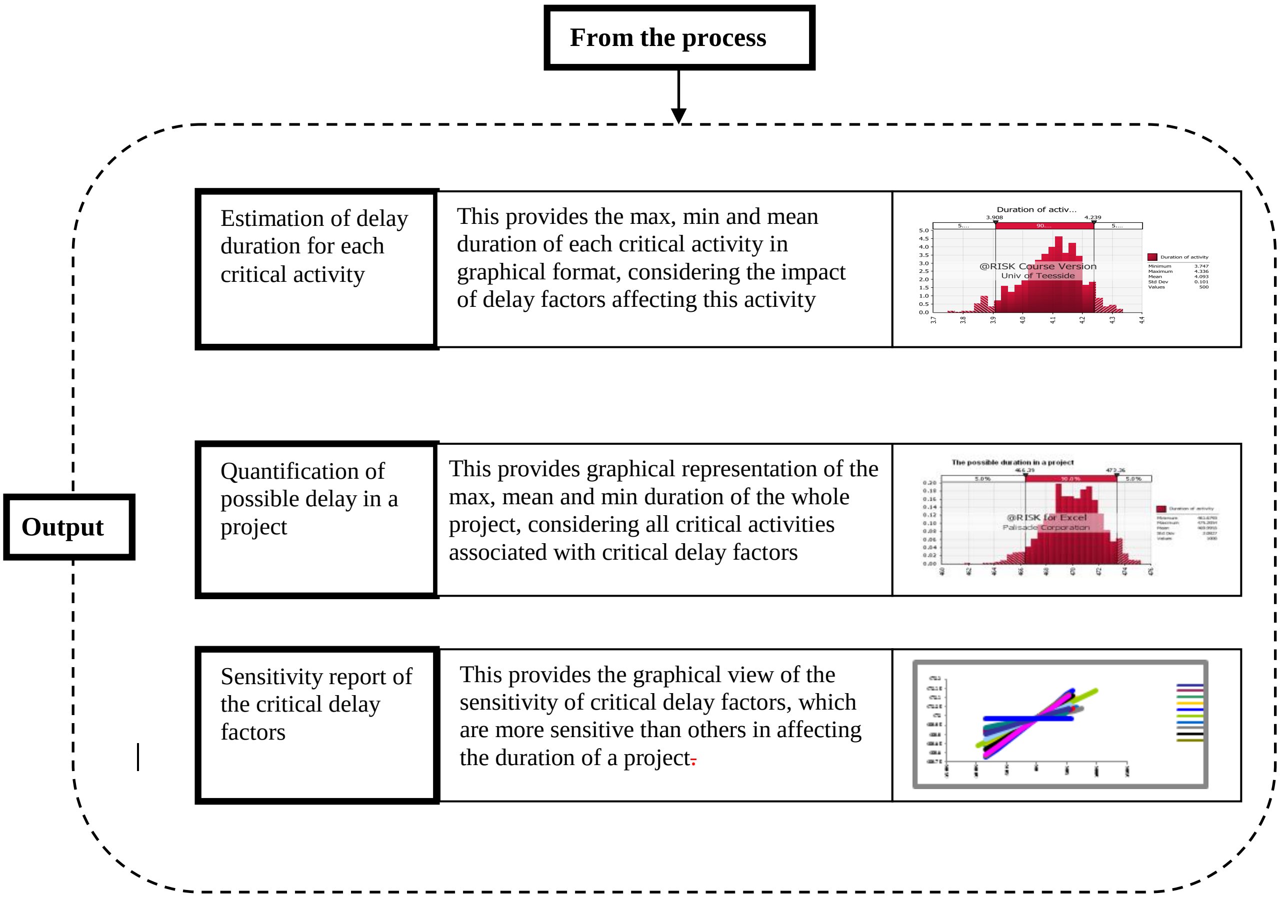


Figure 5.5: Details of DAS outputs

5.6 Chapter summary

The chapter explained the conceptual framework and details of the specifications of the delay analysis system (DAS). The DAS was designed under three parts: input, process and outputs:

- The list of critical delay factors with the IW of each factor and the list of critical activities found in a project are the key inputs of the system.

- The calculation of influence values of each delay factor, and assigning the number of delay factors to each critical activity, are initial processes of the system. The generation of a random number, which is based on the selected risk distribution, and determination of the possible duration of each critical activity, are the main processes included in this system.

- The outputs of the DAS are the possible duration of a project and a sensitivity report of each delay factor considered in the system.

This chapter presented a methodology for analysing delay factors with the aim of quantifying the impact of delay (possible duration of a project) in a construction project which has been affected by a number of delay factors throughout the construction operations. A case study has been selected to analyse and validate the functionality of the system, which is discussed in the next chapter.

Chapter 6-

Development of Simulation Model of Delay Analysis System (DAS)

Chapter 6: Development of Simulation Model of DAS

6.1 Introduction

The previous chapter outlined the conceptual framework design of the Delay Analysis System (DAS) proposed in this study. This chapter describes the development process of the simulation model of the DAS and also explains the processes of the simulation model. The specification of the model is arranged into three parts: input, process and output. The simulation model was developed by integrating '@risk' simulator and MS Excel using Visual Basic Application (VBA). The simulation model is developed with the aim of assisting construction managers in analysing and quantifying the impacts of delay factors in building projects during the construction phases.

Moreover, this section also discusses the development of a process to identify the project risk level in a construction project. Before starting the risk analysis, it is necessary to identify the project risk level in order to take the decision whether to perform a detailed delay analysis of the construction project or not. If the project risk level is found to be average or higher, then a detailed delay analysis is performed using the developed DAS. This is the first stage of the risk management system. The next section discusses the identification process for project risk level followed by the development of the DAS.

6.2 Identification of project risk level

This section presents the identification process for project risk level, which is an independent tool and not integrated within the simulation model of the DAS. The identification process helps the project stakeholders to identify the initial indication of project risk level presented in a construction project, and to decide whether or not to continue identifying and quantifying the impact of the possible delay factors associated with that project.

A risk identification process could be achieved through a multiple-choice questionnaire, enabling project teams to appreciate the project complexity. This ranking is to be considered during the risk identification process. The risk level is identified in a project in order to draw the attention of the project team and to understand the impact of a possible delay in that project. The risk level is identified using a score decided by the project team members through a scoring input form (see Appendix-G, Figure 3).

In the input form, there are five levels of score: 0, 1, 2, 3, and 4. The score 0 means no risk whereas the score 1 means normal risk, 2 means medium risk, 3 means high risk and 4 means very high risk. The project team can select only one of the four options, based on their experience. A total 75 delay factors were used to develop the user form where the project team need to enter their score against each delay factor. These factors have been divided into three groups: group-A, group-B and group-C, with 25 delay factors in each group (see Appendix-G, Figure 3).

A higher score indicates that the project has high sensitivity to possible risks, and the project team has to be more alert in managing the possible risks around those delay factors. The result of the project risk level is shown on a 100%-scale (see Appendix-G, Figure 4). It is a way of highlighting the importance of those project conditions and environments that can increase the possibility of risks occurring.

6.2.1 Report of risk identification

The report of the risk identification process shows the different levels of risk – which may vary from high-risk to normal-risk level – by representing them as an index of different colours (Project Risk Management Handbook, 2007); see Appendix-G, Figure 5). The levels of risk are identified using the score selected by the project team, as set out below.

Score	Level of risk
• Above 81 %	very high risk
• 61 – 80 %	high risk
• 41 – 60 %	average risk
• 20-40 %	medium risk
• Less 20 %	normal

The normal level of risk suggests no possible delay in a project, whereas the very high level risk shows that the project might be delayed by different factors with high impact throughout its duration. After identifying the project risk level, the detailed delay analysis of a construction project is performed if the risk level is shown to be average risk or higher. Hence, the next section discusses the detailed development of the DAS augmented with the simulation model.

6.3 Development of DAS with simulation model

The following sections detail the characteristic factors of the simulation model.

6.3.1 Simple

Construction projects normally suffer from divisions and limitations of the skills of team members on site. In order to achieve success in applying the simulation model of the delay analysis system, it has to be practically simple to use and to rely on existing available technology and tools, with limited training needed for users. Therefore, the system was developed using MS Excel, '@risk' simulator and MS Project. MS Excel and MS Project are widely used as planning and scheduling tools because they are available to the wide range of construction contractors in Libya and worldwide.

6.3.2 Effective

The proposed system has to correspond to the project's need for monitoring and controlling the impact due to delay factors in a construction project. In order to achieve this, the system has to demonstrate the ability to filter and report the impact of delay in a well-organised manner. The project team needs to realise the benefit of the system in managing and reporting the impact of delay. The system is expected to assist in examining the possible threats from delay and in reducing the impact from possible delay.

6.3.3 Flexible

Every project is unique and needs flexibility in applying the developed delay analysis systems. The system needs to be flexible, and capable of being modified in order to fit the project requirements for managing the impact of delay in a construction project. The ability to create different project phases and structures is an essential feature if the success of the system is to be achieved.

6.3.4 Measurable

At any phase of the project lifecycle, delay risks need to be identified and quantified in order to choose the proper risk mitigation method. Quantifying delay factors is the first step towards identifying the actions that need to be taken by the project team. Therefore, the developed system is expected to assist in analysing the delay and measuring its impact due to the possible delay factors in advance, so that the construction manager can take the necessary measures to reduce the delay impact in the project.

6.3.5 Cost effective

Cost effectiveness is the key factor for development of any simulation model or system. Considering the economic factor, the system was developed using MS Excel as a foundation for the simulation model. The advantage of using MS Excel is that users can design their own VBA macros and embed these within the program in order to run additional functions for the development of the DAS. The next section explains about the processes of the simulation model of the DAS

6.4 Processes of the simulation model

Taking into account the findings from the literature review and construction industry survey during the course of this study, the processes of the simulation model of the DAS were designed as shown in Figure 6.1.

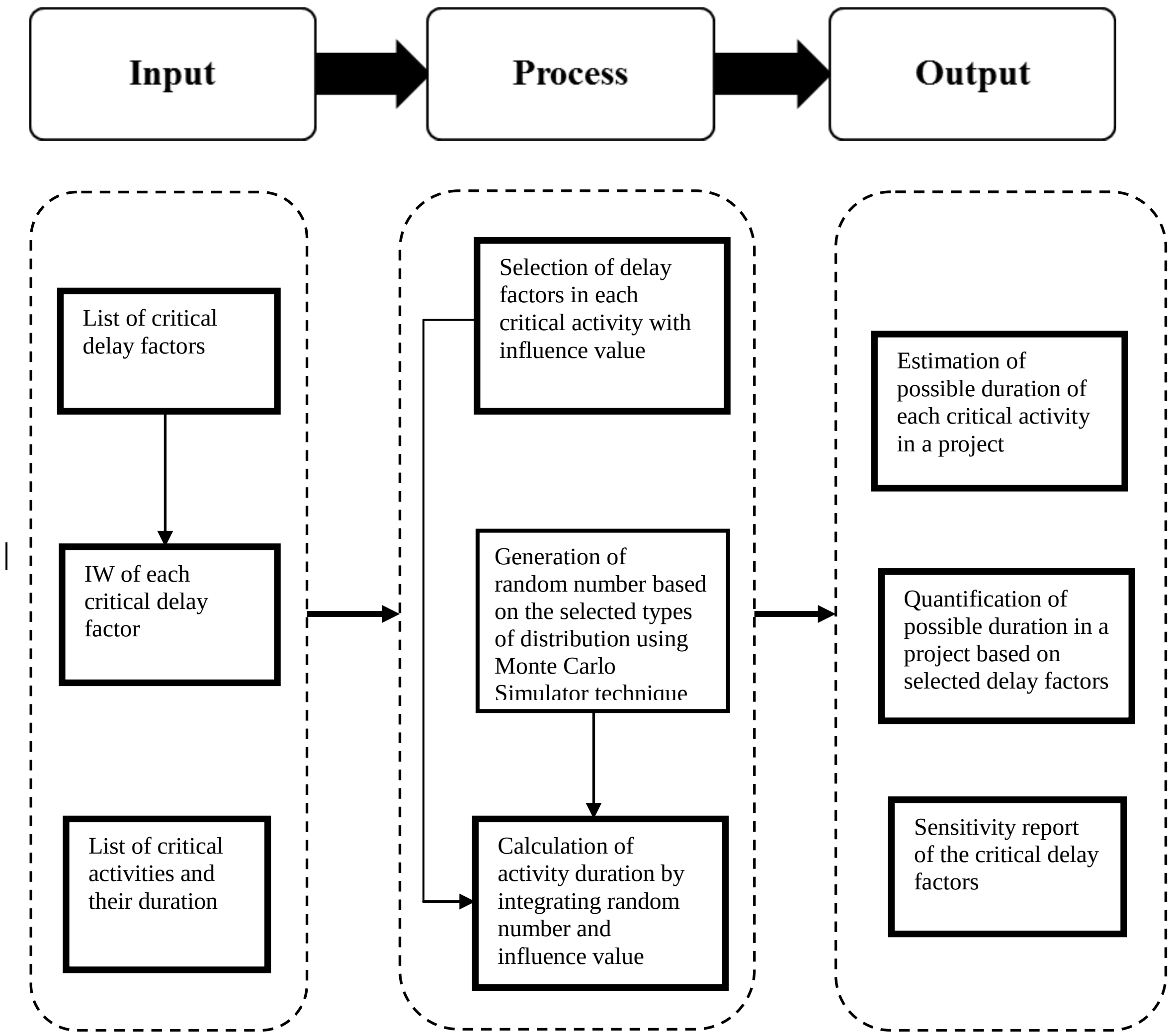


Figure 6.1: Processes of the simulation model of the DAS

The processes of the simulation model of the DAS are arranged into three parts as follows:

1. Input: Data collection;
2. Process: Data processing;
3. Output: Result analysis and reporting.

The system has been divided into three parts: system requirement/data collection (input); data processing (process); and analysing and reporting (output). The system helps to store and manage the required risk data in an effective way, and is expected to assist project stakeholders in controlling the risks during the construction stage.

6.4.1 Input: data collection

This section explains the structure of the input in the simulation model of the delay analysis system. This includes details of the data requirements and its contents. The system is organised into three sub-sections. The first section of the input deals with the required information, including data collection and storage. In the system, the data from the industry survey have been analysed to identify the important weight of delay factors in Libyan and UK construction projects and used an input of the system. The Importance Weight helps to quantify the impact of the possible delay factors in a building construction project. Figure 6.1 presents the processes of the simulation model of the delay analysis system.

The list of delay factors with corresponding IW and the list of critical activities of a construction project were identified first, and then used as inputs for the DAS (for details, see sections 5.3.2 and 5.3.3 in Chapter 5). In the study, only the critical activities have been considered in the simulation model of the DAS, because the author believes that the critical activities are more sensitive than the near-critical activities as far as delay in a construction project are concerned; however, the near- critical activities can also be incorporated in the system.

Furthermore, the possible durations of all near-critical activities need to be calculated first, considering associated delay factors when near-critical activities are considered for delay analysis. These activities then need to be integrated with the DAS and compared with the critical activities in order to determine the new critical path that finally determines the project duration. However, the near-critical activities were not integrated in this study, because there was also an understanding with the construction professional during the site meeting that the critical activities were more sensitive than the near-critical activities. In the developed model of the DAS, the input sheet from MS Excel was used to list the possible delay factors associated with the critical activities of a construction project.

6.4.1.1 List of delay factors with Importance Weight

This is first input of the system. The list of possible delay factors affecting a construction project needs to be identified at a site meeting with construction professionals, as shown in the input sheet of the simulation model. The Importance Weight (IW) of each delay factor, identified by analysing the survey data, is included in the list of delay factors as an input of the model; the theory and formula used to calculate the IW was discussed in detail in sections 4.3 and 4.7 of Chapter 4 and in Appendix B1. A typical example of the list of delay factors and corresponding IWs, used for input of the system, is shown in Figure 6.2.

List of Delay Factors

IW of Each Delay Factor

S.N	List of delay factors considered for input of DAS	IW
1	Shortage of required materials	56.60
2	Delay in materials delivery	75.96
3	Changes in materials prices	50.10
4	Changes in materials specifications	46.63
5	Shortage of required equipment	45.57
36	Lack of experience of owner in construction	65.37
40	Lack of coordination with contractors	57.59
41	Contract modifications (replacement and addition of new work)	82.03
42	Financial problems (delayed payments, and economic problems)	74.08
45	Delay in the settlement of contractor claims by the owner	88.73
46	Delay in issuing of change orders by the owner	84.45
47	Slow decision making by the owner organisation	53.59
48	Interference by the owner in the construction operations	74.98

Figure 6.2: A typical example of delay factors with corresponding IWs, used as an input

6.4.1.2 List of critical activities

This is the second input of the simulation model of the DAS. A schedule of a construction project, including the minimum, mean and maximum possible durations of all activities, was collected from a construction company. The work activities of a construction project were inserted into MS Project and a list of critical activities identified through the program. The detail of the technique used for the identification of the critical activities was discussed in section 5.3.3 of Chapter 5. The list of the critical activities was used as the second input of the simulation model. A typical example of the list of the critical activities (highlighted in red) is shown in Figure 6.3.

Critical Activities

ID	Task Name	Min duration	Duration	Max duration	Start	finish	Predecessors	Total S
1	**Block 1 (BAB TARABLUS)**				**17-May-09**	**24-May-10**		0 days
2	**Structural works**	207.90	231	254.10	17-May-09	02-Jan-10		9 days
3	**General works**	38.70	43	47.30	17-May-09	28-Jun-09		9 days
4	Excavation	[illegible]	4	4.40	17-May-09	20-May-09		9 days
11	**Ground Floor (GF)**	9.90	**11**	**12.10**	**03-Oct-09**	**13-Oct-09**		
12	Ground floor wall & column rebar	1.80	2	2.20	03-Oct-09	04-Oct-09	10FS+90 days	3 days
13	Ground floor wall & column	3.60	4	4.40	04-Oct-09	07-Oct-09	12SS-1 day	0 days
14	Ground floor wall & column concrete	3.60	4	4.40	04-Oct-09	07-Oct-09	13SS	0 days
15	Ground floor slab formwork Slab Formwork	4.50	5	5.50	06-Oct-09	10-Oct-09	14FS-2 days	0 days
16	Ground floor slab rebar fixing	4.50	5	5.50	08-Oct-09	12-Oct-09	15FS-3 days	0 days
17	Ground floor slab concrete	0.90	1	1.10	13-Oct-09	13-Oct-09	16	0 days
18	**Floor 1**	**9.90**	**11**	**12.10**	**14-Oct-09**	**24-Oct-09**		
19	Floor wall & column rebar	1.80	2	2.20	14-Oct-09	15-Oct-09	17	0 days

Figure 6.3: A typical example of critical activities used as an input for the model of DAS

6.4.1.3 Interface of the delay analysis system and simulation model

This section discusses the design of the user interface of the simulation model of the DAS, where the user can operate different functions of the model (process inputs to get outputs) through bottom commands designed in terms of a form. A user interface was designed as a simulation model of the DAS (see Appendix G, Figure 1). A user interface (Window form) appears that shows all the functionalities of the system. The functionalities of the DAS include identification of influence values, generation of a random number for the selected types of risk distribution factor, integration of the influence values and random number, and the calculation of possible durations of each activity. The details of determination methods of these functions are discussed in Chapter 5. The system has additional functions that help to identify the level of risk. The system was designed by developing a number of VBA macros, which were linked under bottom command with the interface of the DAS (see Appendix G, Figure 2).

6.4.2 Process: data processing

In this section, the details of the data processing steps are discussed to provide the information to the user about processing methods. In this process, the system was divided into three sub-sections: identification of the influence value of each delay factor affecting each critical activity; generation of random numbers with selected risk distribution; and integration of delay factors with the critical activities. The details of the process for analysis were also discussed in Chapter 5.

The simulation model of the delay analysis system was developed using Microsoft Excel as a basic platform and the @risk simulator. The possible duration of each activity of a project was calculated using equation 6 (for details, see section 5.4.3 in Chapter 5). The equation is flexible to incorporate the influence value of each delay factor and a random number for risk distribution probability. Individually for each activity of a project, the influence value was calculated using the Importance Weight of each delay factor, which was identified from analysing the survey data using a frequency and severity method.

6.4.2.1 Identification of influence value

This process deals with the identification of the influence value of each delay factor associated with a construction project. This is the key process that determines the impact on project duration, considering the influence value independently in the simulation model of the DAS. The detail of the theory and formulas used for the identification of the influence values was discussed in section 5.4.1 of Chapter 5. A typical example of the integration sheet used to identify the influence value of each delay factor is shown in Figure 6.4.

Influence values of RF

Selection of delay factors affecting each critical activity with IW and influence factors

Critical activity No	Delay factor no	The most critical delay factors in construction industry	IW	Influence factors
13,14	69	Waiting time for approval of drawings	76.73	0.35
	64	Severe weather conditions on the job site	65.27	0.30
	2	Delay in materials delivery	75.96	0.35
			217.96	1.00

Critical activity No	Delay factor no	The most critical delay factors in Libyan construction industry	IW	Influence factors
15,16,17	65	Rise in the prices of materials	59.59	0.30
	56	Delayed and slow supervision in making decisions	84.41	0.42
	1	Shortage of required materials	56.60	0.28
			200.61	1.00

Figure 6.4: A typical example of the influence values calculation sheet of the system

6.4.2.2 Generation of random numbers

This is the second process of the DAS, which deals with the generation of the random number based on the selected type of risk distribution probability, such as triangular, uniform, beta or normal (see section 3.6.7 of Chapter 3). The selection of risk distribution types depends on the nature of delay factors, which is considered independently. The selection process for risk distribution, and for the generation of a random number according to the selected risk distribution using MCS, was discussed in section 5.4.2 of Chapter 5. A typical example of the random number generation sheet of the DAS is shown in Figure 6.5.

Generated Random Number

Integration of random number and influence value											
Activity No	Random 1	Random 2	Random 3	Random 4	Random 5	Rand 1 RF 1	Rand 2 RF 2	Rand 3 RF 3	Rand4 RF 4	Rand 5 RF 5	Duration of activity
GF	C ID 2	C ID 64	C ID 69			C ID 2	C ID 64	C ID 69			
13	0.60	0.50	0.62			0.35	0.30	0.35			4.09
14	0.66	0.60	0.63			0.35	0.30	0.35			4.11
	C ID 1	C ID 56	C ID 65			C ID 1	C ID 56	C ID 65			
15	0.57	0.60	0.50			0.28	0.42	0.30			5.06
16	0.60	0.63	0.59			0.28	0.42	0.30			5.11
17	0.50	0.63	0.55			0.28	0.42	0.30			1.30
F1	C ID 1	C ID 46	C ID 60			C ID 1	C ID 46	C ID 60			
19	0.60	0.57	0.53			0.28	0.41	0.31			2.33
20	0.50	0.56	0.60			0.28	0.41	0.31			4.60

Figure 6.5: A typical example of the random number generation sheet of the model

6.4.2.3 Integration influence value and random number:

This is the main and final process of the simulation model of the DAS. It deals with the integration process of the influence values and random number of delay factors that affect each critical activity of a project. A new coefficient was generated by multiplying the influence value/risk factor and random number (RF*Rand) of each delay factor affecting a critical activity. A typical example of the integration of the random number and risk factor (influence value) sheet of the DAS is shown in Figure 6.6.

Coefficient (Rand*RF)

Integration of the random number and risk factor(influence value)						
Activity No	Integration of the Radom number and risk factor(influence value)					Coefficient
	Rand1 * RF1	Rand2 * RF2	Rand3 * RF3	Rand4 * RF4	Rand5 * RF5	
13	0.209	0.189	0.218			0.616
14	0.230	0.180	0.222			0.631
15	0.160	0.252	0.149			0.561
16	0.169	0.265	0.176			0.611
17	0.179	0.264	0.192			0.634
19	0.167	0.235	0.164			0.566
20	0.153	0.232	0.194			0.579

Figure 6.6: A typical example of the coefficient sheet of the model

6.4.2.4 Identification of possible duration

After integrating the random number and risk factor / influence value, a coefficient was identified. Then, the coefficient was multiplied by the difference of max and min durations of a project activity to identify the expected durations of the activity. The detailed theory and formulas relating to the integration and determination of the possible duration of an activity was discussed in section 5.4.3 of Chapter 5. A typical example of the activity duration calculation sheet of the DAS is shown in Figure 6.7.

Identification of duration

Integration of random number and influence value											
Activity No	Random 1	Random 2	Random 3	Random 4	Random 5	Rand 1 RF 1	Rand 2 RF 2	Rand 3 RF 3	Rand4 RF 4	Rand 5 RF 5	Duration of activity
GF	**C ID 2**	**C ID 64**	**C ID 69**			**C ID 2**	**C ID 64**	**C ID 69**			
13	0.60	0.50	0.62			0.35	0.30	0.35			**4.09**
14	0.66	0.60	0.63			0.35	0.30	0.35			**4.11**
	C ID 1	**C ID 56**	**C ID 65**			**C ID 1**	**C ID 56**	**C ID 65**			
15	0.57	0.60	0.50			0.28	0.42	0.30			**5.06**
16	0.60	0.63	0.59			0.28	0.42	0.30			**5.11**
17	0.50	0.63	0.65			0.28	0.42	0.30			**1.30**
F1	**C ID 1**	**C ID 46**	**C ID 60**			**C ID 1**	**C ID 46**	**C ID 60**			
19	0.60	0.57	0.53			0.28	0.41	0.31			**2.33**
20	0.50	0.56	0.63			0.28	0.41	0.31			**4.60**

Figure 6.7: A typical example of the duration calculation sheet of the simulation model

6.4.3 Output: Reporting simulation results

This section discusses the outputs of the simulation model of the delay analysis system. The outputs of the system include the possible duration of each critical activity and the total duration of a construction project. An additional output of the model is the generation of the sensitivity report of the critical delay factors that affect the construction project. The outputs of the system generated by the model are first reported in the Excel sheet, and these results are also displayed in the different Window forms by designing VBA macros (see Appendix G). The details of the process to get outputs from the system are discussed in section 5.5 of Chapter 5.

In the next section, the reporting of the simulation model outputs, which includes simulation results about project duration and the sensitivity report, is discussed.

6.4.3.1 Simulation of possible duration

This section describes the simulation process to determine the possible duration of an activity of a construction project, independently considering the impact of each delay factor that affects the activity. To identify the expected duration, the inputs of the simulation model (as discussed in the above sections) were processed using @risk simulator. In this simulation model, an equation was used to estimate the possible duration of an activity (see Chapter 5), where min and max duration of activity, random number and risk factor (influence value) are key factors that determine the duration of an activity in the construction project. A typical example of the simulation result of activity duration, achieved by running @risk simulator, is shown in Figure 6.8. The results include max, min and mean duration of activity, including standard deviation and iteration number.

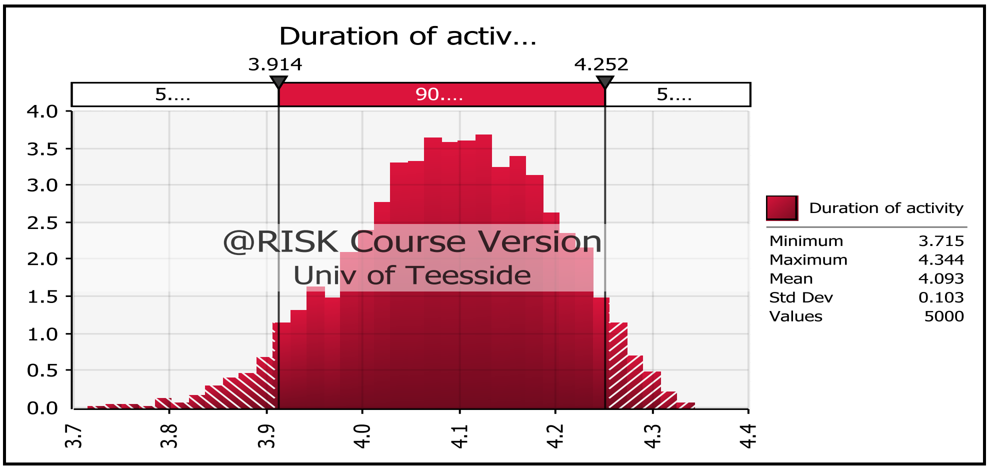


Figure 6.8: A typical example of an activity duration presented in probability distribution

Similarly, @risk simulator was run for each activity, which was critical in the project to determine the possible duration of each activity, considering the random number and risk factor (influence value) of each delay factor independently. The list of project activities with possible durations, after considering the impact of delay factors and the number of iterations completed to run the simulation, are presented in Figure 6.9.

Possible duration of each activity

Act ID	Start date	Finish date	Duration of Act	Duration with Risk	Run times	Probability %
147	**6 March 2010**	**25 March 2010**	**20**	**20.60**	**1000**	**0**
Act ID	**Start date**	**Finish date**	**Duration of Act**	**Duration with risk**	**Run times**	**Probability %**
13	04/10/09	07/10/09	4	4.09	1000	
14	04/10/09	07/10/09	4	4.11	1000	
15	06/10/09	10/10/09	5	5.06	1000	
16	08/10/09	12/10/09	5	5.11	1000	
17	13/10/09	13/10/09	1	1.30	1000	
19	14/10/09	15/10/09	2	2.33	1000	
20	14/10/09	17/10/09	4	4.60	1000	
21	14/10/09	17/10/09	4	4.11	1000	
22	16/10/09	20/10/09	5	5.12	1000	
23	19/10/09	23/10/09	5	5.12	1000	
24	24/10/09	24/10/09	1	2.60	1000	
26	25/10/09	26/10/09	2	2.50	1000	
27	25/10/09	28/10/09	4	4.90	1000	

Figure 6.9: A typical example of activity duration before and after considering the impact of delay factors

After generating the possible durations of each activity and the total duration of a project, and reporting the results in the Excel sheet, a form was designed using VBA macro to display the same simulation results in visual form (see Appendix G, Figures 6 and 7).

6.4.3.2 Report of sensitivity analysis

Sensitivity analysis is a systematic and common-sense technique used to detect the key roles (forces) in estimating risk impact. It is used in both point-estimate and probabilistic approaches to identify and rank significant sources of variability as well as important sources of uncertainty. The quantitative information provided by sensitivity analysis is important for guiding the complexity of the analysis and communicating important results (Chapter 5, section 5.5).

Sensitivity analysis plays a central role in identifying the sensitivity of each delay factor influencing a construction project. Appendix G, together with Figures 9 and 10, provide detailed information in graphical form of the statistical techniques used to determine which variables (delay factors) in the DAS contribute most variation in the estimation of project delay. This variation in delay risk could represent variability, uncertainty, or both, depending on the type of delay factors and the characterisation of input variables (delay factors).

In this section, the sensitivity reports produced by the simulation model of the DAS are presented and explained. The sensitivity analysis focuses on identifying the sensitivity of delay factors affecting an activity or a project. The sensitivity reports are generated after running the simulation with @risk (see Appendix G). The sensitivity report helps to analyse and understand the importance of the risk (delay) factors, stored in the simulation model of the DAS. The report also helps to investigate risks, control actions, programme tasks and allocate the associated risks.

The sensitivity report provides several types of statistical information relating to the project duration of each delay factor, including Mean, Minimum, Maximum, Mode, Median, Standard Deviation, Variance, Kurtosis, Skewness, 5^{th} Percentile, and 95^{th} Percentile of a project. The results shown in the sensitivity report of each delay factor assist the project or construction manager in analysing the impact of each delay factor, and help them take necessary measures to reduce the impact of each delay factor individually.

6.5 Chapter summary

This chapter discussed the development of a simulation model augmented with a delay analysis system, and also explained the detailed processes of the simulation model. The model was developed into three parts – input, process and output – by integrating it with @risk simulator. The inputs were collected from the results of the industry survey and the site meeting conducted with construction professionals. The inputs were processed by developing a simulation model based on an MS Excel sheet underpinned with the equations discussed in the specification section. The outputs of the model were reported in Excel sheets and displayed through different forms by designing the VBA macros within MS Excel. The simulation model is expected to assist construction managers in analysing and quantifying the impacts of delay factors in building projects during the construction phases.

The chapter also discussed the process of identifying project risk levels that is available in a construction project. This is expected to assist in controlling the risks associated with construction projects. The project team has the ability to practise a simple qualitative exercise of analysing project risks which can guide them in the right direction towards controlling those risks. The next chapter focuses on evaluating the functions of the developed simulation model of the delay analysis system with case studies.

Chapter 7-

Evaluation of the Simulation Model of the Delay Analysis System (DAS)

Chapter 7: Evaluation of the Simulation Model of the DAS (Delay Analysis System)

7.0 Introduction

This chapter presents the details of the evaluation processes of the Delay Analysis System (DAS) augmented with the simulation model. In this study, two case studies from building projects were used to analyse and quantify the impact of risks (delay factors) using the information collected from the construction professionals associated with the case studies. This chapter also describes the detailed reviews of the background of the two case studies, selected from building construction projects with the aim of understanding the construction processes and identifying the delay factors associated with the projects, particularly in the case of the Libyan construction industry.

Furthermore, this chapter discusses the detailed processes used to run the case studies and outlines the evaluation steps of the DAS. At the first stage, the available risk level of a construction project is identified before starting the simulation with the DAS in order to take the decision whether to execute a detailed analysis of the project with the DAS. This section also discusses the evaluation of the risk identification process in the selected case studies.

The DAS was developed to assist construction managers and stakeholders to analyse and quantify the possible impact of delay factors on construction projects. Project managers can take appropriate decision and necessary measures to reduce the impact of delay factors before starting a construction project or during the implementation stage to avoid further delay. The next sections discuss the background of the case studies.

7.1 Background of case studies:

Generally, construction projects vary in size, type of contract, and the nature of the project itself. Normally, each construction project will experience some sort of delay due to the variable risks (factors) that influence it. Therefore, two case studies from building projects in Libya were selected to review the nature and extent of delay factors that affect construction projects. These case studies are:

1) **Case study 1:** Taric Al-Mataar building construction project
2) **Case study 2:** Educational and office building project.

7.1.1 Taric Al-Mataar building construction project

The Taric Al-Mataar construction project was one of the largest housing projects in the south of Tripoli city in terms of its complexity and construction activities. The project comprised more than 280 housing flats and the project value was LD 14,660,568 million. The project was awarded via a turnkey contract approach for the design and construction of ten blocks, where each block included seven floors and each floor contained four flats. The owner of the building project was the Ministry of Building (Libya). The project was started in May 2009 by the Turkish construction company Eessage. Photographs of the project under construction are shown in Figures 7.1, 7.2 and Appendix-I.

Figure 7.1: Photograph of the project under construction

Figure 7.2: Photograph of the project under construction

The Taric Al-Mataar construction project was selected as a case study in order to analyse and evaluate the impact of delay factors using the developed simulation model of the delay analysis system. The reasons for the selection of this case study were as follows:

- The project was under construction and accessible to collect the required data for case study analysis;
- The project team had not considered the importance of risks and their impact on delivery, and they were interested in analysing the possible delay impacts;
- The risks associated with the project had high impact in terms of the project cost and duration, and even a chance of project failure;
- The researcher believed that the project had not properly analysed or responded to the possible risk before the commencement of works. Therefore, a proper delay analysis system might add some considerable value to reduce the impact of delay factors associated with the project output.

7.1.2 Review of risks associated with case study 1

A meeting was arranged with the construction manager and site engineers of the project as part of the review case study. The aim of the review meeting was to identify problems faced by the construction project and to prepare a list of critical delay factors associated with it. During this review of the project, the following observations were made:

1. Observations associated with construction material:
   - It was recognised that cement, steel, concrete and brick (stone) were the key construction materials;
   - Cement and steel were obtained from the state's plants and international markets. Concrete was produced by a central mixer plant. It was noted that water was treated before using it in producing concrete;
   - One of the site managers highlighted that the production of concrete was carried out during the early morning or at night in order to avoid the negative impact of high temperatures on the processes of concrete production, thereby improving the quality and reducing the evaporation of water from the concrete;
   - The visual survey showed that the majority of construction materials were based on cement and its related products;
   - It was observed that the local market in Libya lacked a supply of electrical and sanitary fittings. The majority of sanitary fittings (toilets, baths, sink taps, etc.) and electrical components were therefore imported from international markets.

2. Observation associated with manpower:
   - It was observed that the majority of manpower (skilled and unskilled) was non-Libyans;
   - Around 10% of the skilled workers were from Libya and the rest were foreign workers;
   - It was observed that casual workers were brought in from the local market to carry out some daily work such as loading and handling of materials, and cleaning work;
   - It was found that there was a long processing time (for acquiring the visa and insurance) when bringing in overseas skilled and unskilled workers to work in the Libyan construction industry.

3. Observation associated with the delay factors:

A total of 24 out of 75 critical delay factors were identified as major influencing delay factors on the construction project, selected as case study 1. The list of observed delay factors, which were collected from the site meeting, was included in the simulation model of the DAS. The Importance Weight (IW) of the identified delay factors was calculated by analysing the industry survey data (discussed in Chapter 4). A list of the observed delay factors with IW is presented in Table 7.1**.**

Table 7.1: Possible delay factors affecting the construction project

DF ID No	Selection of delay factors with IW in each critical activity	IW
1	Shortage of required materials	56.60
2	Delay in materials delivery	75.96
3	Changes in materials prices	50.10
4	Changes in materials specifications	46.63
5	Shortage of required equipment	45.57
36	Lack of experience of owner in construction	65.37
40	Lack of coordination with contractors	57.59
41	Contract modifications (replacement and addition of new work)	82.03
42	Financial problems (delayed payments, and economic problems)	74.08
45	Delay in the settlement of contractor claims by the owner	88.73
46	Delay in issuing change orders by the owner	84.45
47	Slow decision-making by the owner organisation	53.59
48	Interference by the owner in the construction operations	74.98
51	Delay in the preparation of drawings	72.03
53	Poor design and delays in design	63.85
55	Absence of consultant’s site staff	50.63
56	Delayed and slow supervision in making decisions	84.41
57	Poor planning and incomplete contract documents	83.20
58	Slowness in giving instructions	63.10
60	Changes in the scope of the project	62.89
61	Ambiguities, mistakes, and inconsistencies in the drawings	60.86
64	Severe weather conditions on the job site	65.27
65	Rises in the prices of materials	59.59
69	Waiting time for approval of drawings and test samples of materials	76.73

During the site visit to the project, it was found that the project was facing several problems due to the lack of skilled local workers and local building materials. Another problem was temperature variation due to hot weather throughout the construction period. It was also found that the project was using primavera as a planning system, where risks (delay factors) associated with the project were considered according to the past experience and subjective decisions of the construction professionals involved. The project to construct and deliver the project was awarded via a turnkey contractual approach, meaning that the majority of project risks were transferred to the contractor. According to the above points observed during the site visits, it can therefore be concluded that the factors causing the delays to the building project are similar to the delay factors identified from the earlier construction industry survey, conducted in Libya during the course of this study. The author believes that the contractor needs to be ready to incorporate the delay factors stated above into the project planning, in order to avoid delays and to ensure that the project is delivered the project to the fixed timeframe specified in the contract.

The next section discusses the background review of the second case study selected for this study.

7.1.3 Educational and office building project: Case study 2

The educational and office building project from the public sector was selected as a second case study. The project was also awarded on a turnkey contract basis for the design and construction of a total floor area of 1,200 m^2. The project value of the educational and office building, which is located at the Academy of Graduate Studies, Tripoli, Libya, was LD 5,000.000 million, and the owner of the building project is the Saving & Investment Bank (Libya). The project was completed in 2004-2005 by one of the Libyan private-sector construction companies, and was programmed using MS Project. The total agreed project duration was fixed at 11 months, in order to deliver the project according to the specifications and contract drawings. A photograph of the building project is shown in Figure 7.3 below.


Figure7.3: A photograph of the building project

The project faced massive challenges, including the bankruptcy of the concrete and drainage works subcontractor, adverse weather conditions, materials delays, and changes in the scope of the project during the critical time of the project period. These factors, in turn, led to a two-month delay in for project completion.

The project was delivered within the extended time due to the good performance of the contractor company. An appreciation certificate was awarded to the company by the owner for the extraordinary effort made by the company’s project team members. This helped to waive the penalties stated in the contract document. The majority of problems were created by design faults and by the project architect who the owner had appointed. The expertise of the contractor and its professional team members helped the project to be handed over in time before the start of the academic year, as agreed in the contract.

7.1.4 Review of project risks associated with case study 2

In this case study, it was found that the extensive change orders in project scope that had been issued were a major cause of delay by the contractor. This resulted in a substantial financial loss in the project because the contractor had failed to forecast the possible change orders and the associated future problems. These problems affected the quality of the finishing activities of the project and the relationship with the owner because of the pressures exerted by the project end-users who hadn't received their facilities as promised. The contractor’s staff who worked on the project was also under massive pressure from the owner. Change orders caused further problems for the company's bonus scheme, which was linked to the project's profitability. It was also found by the author that the building project selected for case study 2 used MS Project for its planning and scheduling process, and that the past experience of construction professionals was used for analysing and managing the delay risks associated with the project.

The following delay factors (risks) faced by the construction project were observed throughout the construction period:

- The risks or delay factors were unclear to the project construction team;
- The absence of collaboration between the project team to control the delay factors;
- Change orders from the owner and design faults by the architect, causing delays to the project;
- The financial risk due to the bankruptcy of subcontractors also delayed the project;
- The project was delivered before the start of the academic year, though it missed the delivery time specified in the contract.

A total of 22 out of 75 critical delay factors, as shown in Table 7.2, were identified by project team members as major influencing delay factors that had caused the delay in the building project. A list of 75 critical delay factors was identified from the industry survey, which was conducted in Libya during the course of study. It was agreed that, in future, the contractor would need to forecast the possible delay and for this to be incorporated into the tender in order to avoid the loss of time in projects. The next section discusses the evaluation process of risk level identification followed by the simulation of case studies using the DAS.

Table 7.2: Possible delay factors affecting the construction project case study-2

DF ID No	Selection of delay factors with Libyan IW in each critical activity	IW
1	Shortage of required materials	56.60
2	Delay in materials delivery	75.96
4	Changes in materials specifications	46.63
8	Inadequate equipment used for the works	41.32
10	Low skill of manpower	68.97
13	Shortage of technical professionals in contractor's organization	46.99
41	Contract modifications (replacement and addition of new work)	82.03
42	Financial problems (delayed payments, and economic problems)	74.08
43	Delay to delivering the site to the contractor by owner	82.93
45	Delay in the settlement of contractor claims by the owner	88.73
46	Delay in issuing of change orders by the owner	84.45
48	Interference by the owner in the construction operations	74.98
50	Poor qualification of consultant engineer's staff	90.25
51	Delay in the preparation of drawings	72.03
53	Poor design and delays in design	63.85
56	Delayed and slow supervision in making decisions	84.41
57	Poor planning and incomplete contract documents	83.20
60	Changes in the scope of the project	62.89
61	Ambiguities, mistakes, and inconsistencies of drawing	60.86
64	Severe weather conditions on the job site	65.27
65	Rise in the prices of materials	59.59
69	Waiting time for approval drawings and test samples of materials	76.73

7.1.5 Discussion findings between two case studies

In case study-1, a total of 24 delay factors affect the building project (Table 7.1) whereas 22 delay factors affect case study-2 (Table 7.2). Some delay factors (changes in materials prices; shortage of required equipment; lack of experience of owner in construction; lack of coordination with contractors; slow decision-making by the owner organisation; absence of consultant's site staff; and slowness in giving instructions) are unique in only affecting case study-1, whereas other delay factors (inadequate equipment used for the works; low skill of manpower; shortage of technical professionals in contractor's organisation; delay in delivering the site to the contractor by the owner; and poor qualifications of consultant engineer's staff) only affect case study-2. The remaining delay factors (shortage of required materials; delay in materials delivery; changes in materials specifications; contract modifications; financial problems; delay in the settlement of contractor claims by the owner; delay in issuing of change orders by the owner; interference by the owner in the construction operations; delay in the preparation of drawings; poor design and delays in design; delayed and slow supervision in making decisions; poor planning and incomplete contract documents; changes in the scope of the project; ambiguities, mistakes, and inconsistencies of drawing; severe weather conditions on the job site; rise in the prices of materials; and waiting time for approval drawings and test samples of materials) affect both case studies. However, some similar delay factors with different influence values affect the projects when integrated with work activities in those projects, although the importance weights (IW) of each delay factor are similar in both case studies.

7.2 Evaluation of risk level identification

This section discusses the process of identifying the project risk level associated with a construction project, which is an independent tool not integrated within the simulation model of the DAS. The development of the tool was discussed in Chapter 6. This is an additional section of the study that mainly focuses on identifying the possible level of risk presented on a construction project using the subjective information collected from team members at the start of a project. This provides initial information to construction managers about the level of risk that may affect the project. The next section gives a step-by-step explanation of the identification process of the project risk level tool.

7.2.1 Storage of user information

In this section, user (project team member) information needs to be stored for each project through a user input form (see Figure 7.4). The input of user information is the first step that needs to be completed during the identification of the risk level. The user is responsible for the collection of site information and for identifying the risk level using the tool.

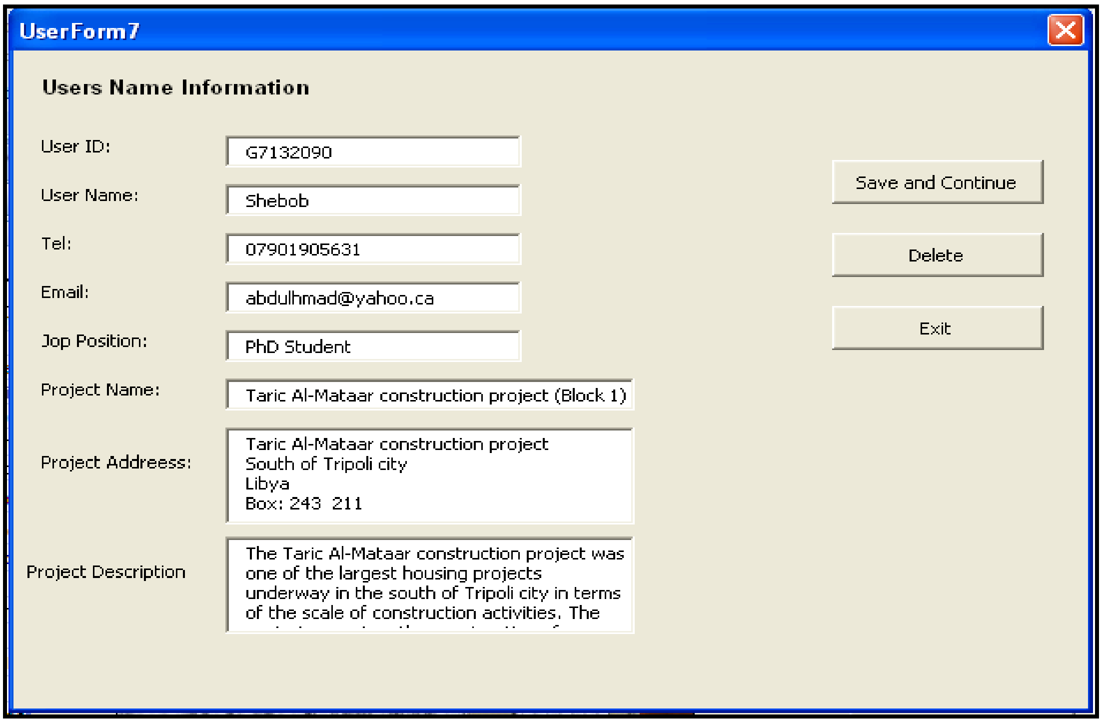


Figure 7.4: System users input form

The user information form includes the user ID, general user information, the project name and address, and a brief description of the construction project.

In this tool, the risk level is identified using a score decided by project team members subjectively through a scoring input form (see Figure 7.5). The system summarises the scores of each delay factor and determines the total risk level score using a form (see Figure 7.6).

For identifying purposes, the score shown in the form (Figure 7.5) was collected from the team members of the case study 1 project in Libya during a site visit in December 2009. The scores provided by the team members were updated in the system. After updating the score of each delay factor, the system calculated the risk level as 48% (see Figure 7.6), shown in yellow in Figure 7.7. The result confirmed that the level of risk was average considering all possible risks (delay factors) associated with the building project in case study 1.

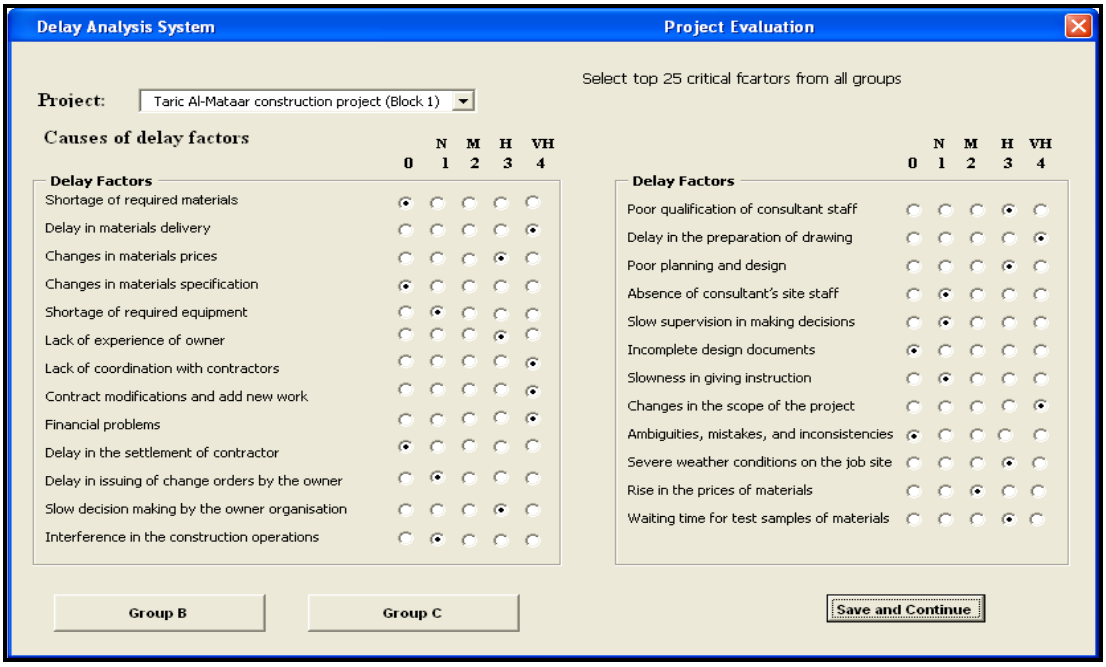


Figure 7.5: Input form with project team's scores

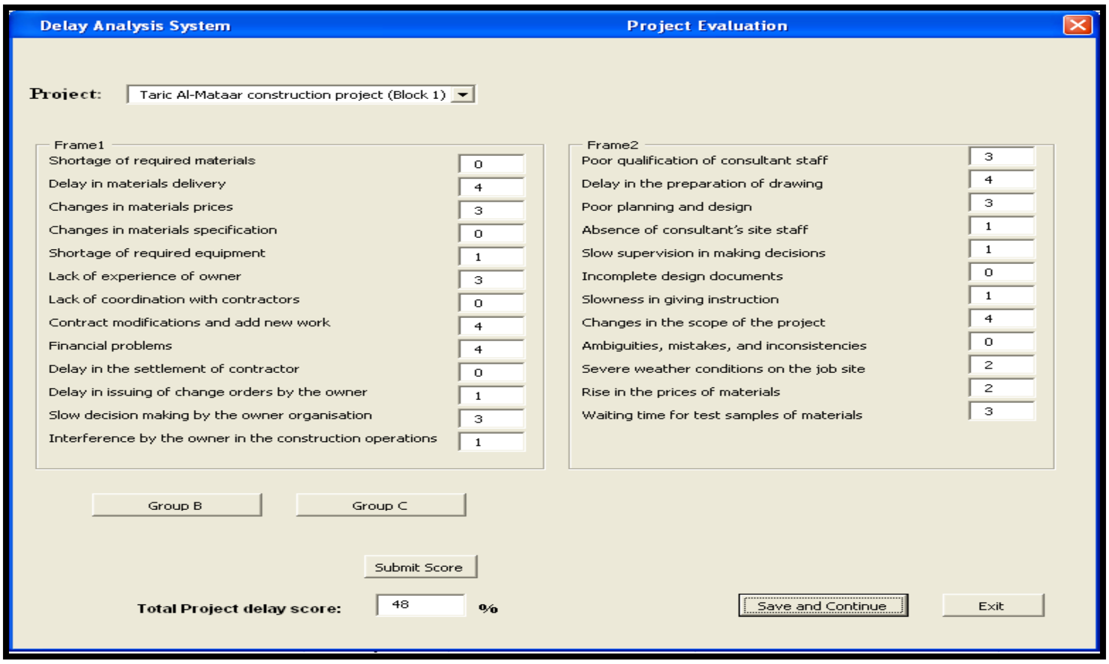


Figure 7.6: Evaluation project system

7.2.2 Report of risk identification

The report of the risk identification process shows the levels of risk identified using the scores selected by project team. The system calculated the risk level as 48%, shown in yellow in Figure 7.15.

Figure 7.7: Report of risk evaluation

7.2.3 Discussion of the risk level results

Since the 48 % risk level that was found for case study 1 is higher than the medium risk level (40%), it is necessary to evaluate the risk using the simulation model of DAS to. Similarly, the risk level identified for case study 2 was 60%. Therefore, both case studies need to be analysed and evaluated with the simulation model of the DAS, which is discussed in the next two sections.

7.3 Evaluation of DAS with case study 1 (Taric Al-Mataar building project)

This section discusses the evaluation of the simulation model of the delay analysis system (DAS) through case study 1. The aim of evaluating the simulation model of the DAS is to analyse and test the functions of the model. The evaluation of the system was performed by quantifying the impact of delay factors associated with the building construction project, using the developed simulation model of the DAS. The evaluation of the case study is presented in three sub-sections: collection of site information; processing of the input data using the developed simulation model of the DAS; and presentation of the simulation results found from case study 1.

7.3.1 Collection of site information

At this stage, the construction schedule of the building project selected for case study 1 was collected from the construction company in Libya during a site meeting with the project team members. The site meeting was conducted in order to acquire information about critical and non-critical activities, activity and project duration, and the relationship of predecessor and successor work activities. It was also noted that case study 1's project schedule was 373 days, showing the starting date as 17/05/2009 and the finishing date as 24/05/2010. During the meeting, a list of critical activities of the project, which were identified from the construction schedule (see Appendix C-1), were discussed with the project team, who agreed and recorded a list of critical activities for use as input data in the simulation model. As discussed in section 7.1.2, a list of potential delay factors associated with the building project was given at the site meeting (see Table 7.1). The key information about critical delay factors affecting each critical activity was identified and recorded from the construction professionals at the site meeting. Using the site information, the influence values of each delay factor associated with the critical activities was calculated, was and then used as a major input of the simulation model. The next section discusses the calculation of the influence value.

7.3.2 Calculation of influence value (risk factor)

This section explains the process of calculating the influence value of each delay factor associated with each critical activity of the case study 1 building project. In this case study, a total of 53 critical activities were listed, and considered for analysis using the simulation model. In this section, the delay factors associated with two critical activities (nos. 13 and 14) are demonstrated, in order to calculate the influence value of those delay factors.

In this case study, work activities numbers 13 and 14 were identified as critical activities, and both activities were affected by three main delay factors: waiting time for the approval of drawings and samples; severe weather conditions; and delays in materials (see Table 7.2).

The Importance Weight (IW) of each delay factor affecting the critical activities was identified through the industry survey (see Chapter 4). The IW of the delay factors (ID nos. 69, 64 and 2) were identified as 76.73, 65.27 and 75.96 respectively (see Table 8.2). The influence values (risk factors) of delay factors associated with the critical activities were calculated using equation 5 (for details see Chapter 5). In this case, the influence values of the three delay factors (ID nos. 69, 64 and 2) affecting the critical activities (ID nos. 13 and 14) were found as 0.35, 0.30 and 0.35 respectively (see Table 7.3). Similarly, the influence values of five delay factors affecting critical activities numbers 50, 51 and 52 were calculated and presented in Table 7.4 below. The influence values of the rest of delay factors associated with the critical activities were calculated and are shown in Appendix D 1**.**

Table 7.3: Activities 13 and 14 with risk

Critical activity No	**Causes ID NO**	**The most critical delay factors in Libyan construction industry**	**IW**	**Influence factors**
13,14	69	Waiting time for approval of drawings and test samples of materials	76.73	0.35
	64	Severe weather conditions on the job site	65.27	0.30
	2	Delay in materials delivery	75.96	0.35
			217.96	1.00

Table 7.4: Critical activities nos. 50, 51 and 52 with delay and influence factors

Critical activity No	**Causes ID NO**	**The most critical delay factors in Libyan construction industry**	**IW**	**Influence factors**
50,51,52	45	Delay in the settlement of contractor claims by the owner	88.73	0.28
	5	Shortage of required equipment	45.47	0.14
	3	Changes in materials prices	50.10	0.16
	2	Delay in materials delivery	75.96	0.24
	1	Shortage of required materials	56.60	0.18
			316.86	1.00

7.3.3 Generation of random number

This section discusses the generation of a random number for each delay factor (risk factor), considering the suitable types of risk distribution. The critical delay factors found from the industry survey were considered as risk factors for analysing the impact of delays in the project. The types of distribution of each delay factor were selected by the author, considering the nature and impact level of the delay factors. For example, triangle and uniform distribution of risk factors were selected for all delay factors to generate the random numbers for the simulation model (see section 6.4.2.2 of Chapter

6). The random numbers and influence values of the critical delay factors associated with each critical activity of the building project are shown in Appendix F-1.

7.3.4 Calculation of activity duration

This section discusses the process of calculating the duration of each critical activity within the selected building project (case study 1). The duration of each critical activity was calculated using Equation 6 (see Chapter 5). The detailed methodology for generating the random number and risk factors was discussed in Chapter 6. The simulation model of the DAS was used to calculate the duration of each activity. For example, the result of activity number 149 was found as 20.62 days after considering the impact of delay factors associated with the activity. The activity was estimated at 20 days. The result can also be displayed in a form as shown in Figure 7.8.

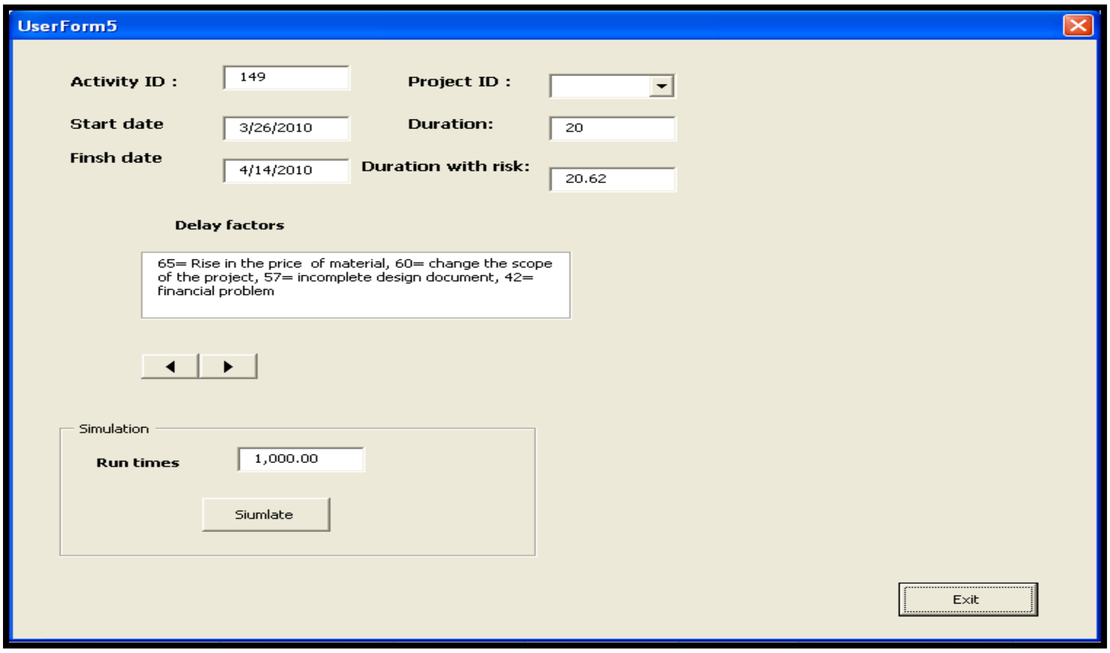


Figure 7.8: Window form showing the duration of an activity predicted by the DAS

Similarly, the durations of other activities were identified using the processes discussed above. The detailed results from case study 1 are discussed in the next section.

7.3.5 Simulation results of case study 1

In this case study, the building project was analysed to quantify the project duration, taking into account the impact of delay factors. Using the information discussed in the sections above (such as critical activities, influence values, random numbers and equations), the possible duration of the building project was quantified through the simulation model of the DAS. The simulation was run with 1,000 iterations to determine the durations of the project activities, and the results are presented in Figure 7.9. The figure shows that the project duration was predicted at around 470 days after considering a total of 24 critical delay factors. However, the project was originally estimated at 373 days. Comparing these values, it was found that the project might be delayed by 97 days when taking into account the delay factors.

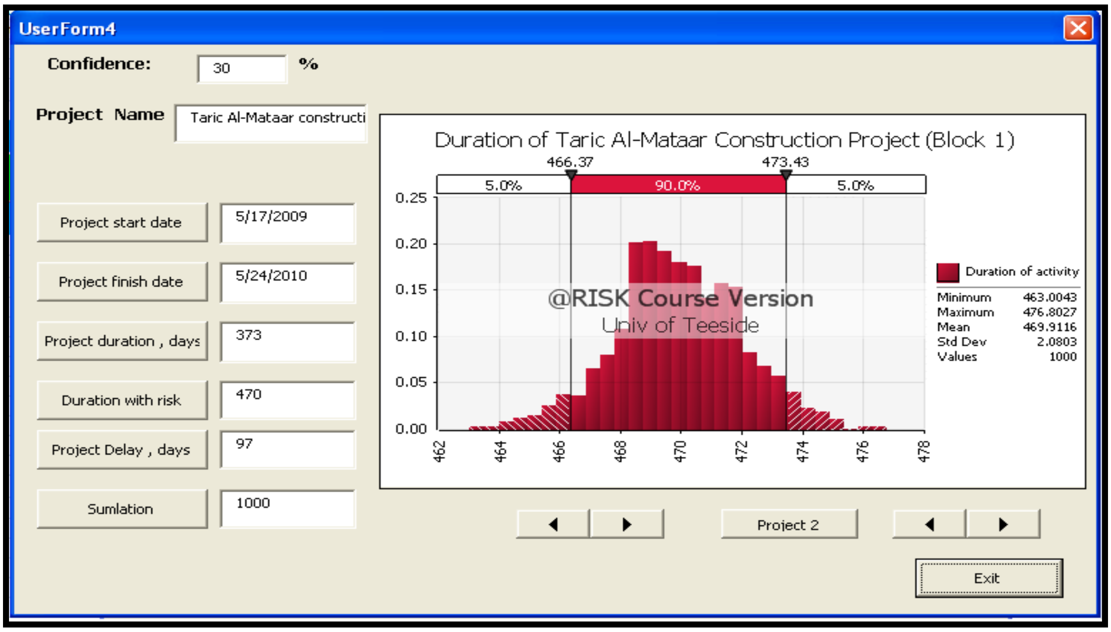


Figure 7.9: Distribution of possible project duration for case study 1

7.3.6 Discussion of model results evaluation:

In case study-1, the project was stopped before final completion delivery to the client due to the unexpected Libyan war in 2011. Therefore, data for the actual duration of project activities and the whole project are missing, and the model results were evaluated by comparing them with the planned duration of the project (information that was collected during the site survey).

After comparing the model result with the planned duration of the project selected for case study-1, it was found that the minimum possible duration of the building project was 463.01 days; that the maximum was 476.80 days; and that the mean was 469.91 days. The average planned duration of the project was found to be 373 days, which is lower than the model-calculated possible duration of 470 days (97 days higher than planned duration) when considering the possible delay factors affecting the project.

The figure above regarding possible delay duration of the project confirms that the case study project would be expected to be delayed by 97 to 103 days when considering associated delay factors on the project. If all delay factors were incorporated into the simulation model, the project might be delayed by more than the time found in the results, leading to different project duration. The author believes that the system was successful in analysing and quantifying the impact of delay factors associated with the building, helping construction managers to predict the project duration more rationally, and to reduce the impact of delays in terms of project duration.

7.3.7 Sensitivity reports of case study 1

This section explains the sensitivity reports produced by the simulation model of the delay analysis system. The report provides information on project start date, finish date and project duration, before and after consideration of the impact of delay factors. A sensitivity graph of associated delay factors that contributed to the project delay, which has been generated from the simulation model, is shown in Figure 7.10.

The figure 7.10 mainly provides the information about the possible duration of project due to major delay factors that occurred in the project in term of graphs. The graphs show the variation in project durations due to the variation in positive and negative probability of each delay factors (start from +100 % to o and o to – 100%). The slope of line presents with different colours for different delay factors. If the slope is steep, then the delay factor is highly sensitive and the duration of project varies high between 0 % and 100% of probability. For example delay factors ID no 2 found the highly sensitive due to top among all delay factors. The possible mean duration of the project may be varies from 474.84 to 475.06 days at 1% and 99% probability of the occurrence of the delay factors. This mean how the variation of each delay factor affects in the project duration from the level of occurrence probability can be quantified and use such information to take necessary measure aiming to reduce the impact of the delay factor in the project.

The major delay factors considered in analysing the project duration were: slow supervision in making decisions, a shortage of required materials, changes in the scope of the project, incomplete design documents, severe weather conditions on the job site, delays in material delivery, a lack of experience of the owner in construction, interference by the owner in the construction operations, and a rise in the price of materials were, among others, the most critical delay factors. These factors were included in the quantification of the project delay for the Taric Al-mataar construction project in case study 1 (see figure 7.10).

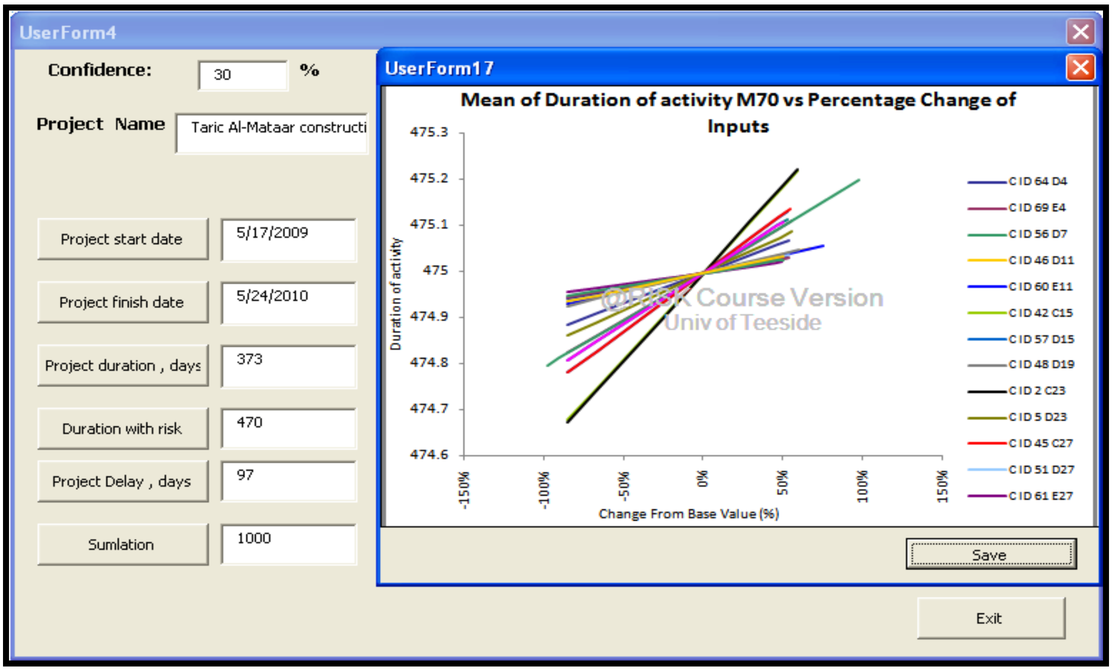


Figure 7.10: Snapshot of sensitivity reports of case study 1

The sensitivity report provides different types of statistical information about the possible project duration when considering delay factors associated with the Libyan construction industry. The statistical information includes the Mean, Minimum, Maximum, Mode, Median, Standard Deviation, Variance, Kurtosis, Skewness, 5th Percentile and 95th Percentile of project duration (Figure 7.11). For example, in relation to the delay factor ID no. 64, the possible duration of the project has different impacts at different levels of probability (from 1%, 5%, 25%, 50%, 75%, 95% and 99%). In addition to these values, the sensitivity report also provides detailed information regarding the possible duration of the project at all probability levels. For example, at 50% probability level of occurrence, the mean duration of the project is 475.00 days, the minimum possible duration 469.07 days, and the maximum possible duration 481.48 days, with a standard deviation value of 2.09 in all these possible durations of the project when conceding delay factor no. 64 (see Figure 7.11).

Similarly, all critical delay factors were analysed to identify the sensitivity of each one in terms of possible project duration (with probability ranging from 1% to 99%; see Figure 7.11). The sensitivity report assists the project manager in understanding the gravity of each delay factor on the project duration at different levels of probability.

Advanced Sensitivity Analysis Summary Report

Performed By: g7132090
Date: 30 July 2010 11:50:51
Output: Duration of activity
Inputs Analyzed: 19
Simulations: 133

Input		Output: Duration of activity											
Name	Analysis	Value	Mean	Min	Max	Mode	Median	StdDev	Var	Kurtosis	Skewness	5%	95%
C ID 64	Perc%: 1%	0.094339811	474.8850324	468.9591561	481.3611335	474.9799194	474.9878348	2.096326846	4.394586246	2.804938952	-0.101573855	471.2492174	478.2698747
C ID 64	Perc%: 5%	0.210950231	474.9092873	468.983411	481.3853885	475.0041744	475.0120898	2.096326846	4.394586246	2.804938952	-0.101573855	471.2734723	478.2941297
C ID 64	Perc%: 25%	0.471699057	474.9635231	469.0376468	481.4396242	475.0584102	475.0663255	2.096326846	4.394586246	2.804938952	-0.101573855	471.3277081	478.3483654
C ID 64	Perc%: 50%	0.667083203	475.004163	469.0782867	481.4802641	475.0990501	475.1069654	2.096326846	4.394586246	2.804938952	-0.101573855	471.368348	478.3890053
C ID 64	Perc%: 75%	0.817006732	475.0353471	469.1094708	481.5114482	475.1302342	475.1381495	2.096326846	4.394586246	2.804938952	-0.101573855	471.3995321	478.4201894
C ID 64	Perc%: 95%	0.925838015	475.057984	469.1321077	481.5340851	475.1528711	475.1607864	2.096326846	4.394586246	2.804938952	-0.101573855	471.422169	478.4428263
C ID 64	Perc%: 99%	0.966833752	475.0665111	469.1406348	481.5426122	475.1613982	475.1693135	2.096326846	4.394586246	2.804938952	-0.101573855	471.4306961	478.4513534
C ID 69	Perc%: 1%	0.092736185	474.8235166	468.9350509	481.1141879	474.5107468	474.923248	2.097272743	4.398552958	2.775039858	-0.10433129	471.1757568	478.1853537
C ID 69	Perc%: 5%	0.207364414	474.8611147	468.9726489	481.151786	474.5483449	474.960846	2.097272743	4.398552958	2.775039858	-0.10433129	471.2133549	478.2229518
C ID 69	Perc%: 25%	0.463680925	474.9451865	469.0567208	481.2358578	474.6324167	475.0449178	2.097272743	4.398552958	2.775039858	-0.10433129	471.2974267	478.3070236
C ID 69	Perc%: 50%	0.655743852	475.0081831	469.1197174	481.2988544	474.6954134	475.1079145	2.097272743	4.398552958	2.775039858	-0.10433129	471.3604233	478.3700203
C ID 69	Perc%: 75%	0.80311892	475.0565222	469.1680564	481.3471935	474.7437524	475.1562535	2.097272743	4.398552958	2.775039858	-0.10433129	471.4087624	478.4183593
C ID 69	Perc%: 95%	0.916333997	475.0936567	469.205191	481.384328	474.7808869	475.193388	2.097272743	4.398552958	2.775039858	-0.10433129	471.4458969	478.4554938
C ID 69	Perc%: 99%	0.962583426	475.1088265	469.2203608	481.3994978	474.7960567	475.2085579	2.097272743	4.398552958	2.775039858	-0.10433129	471.4610667	478.4706636
C ID 56	Perc%: 1%	0.01	474.7955492	468.7755632	481.2009273	475.4616711	474.8871822	2.092620759	4.37906164	2.804559233	-0.109868761	471.1373705	478.1604011
C ID 56	Perc%: 5%	0.05	474.8119492	468.7919632	481.2173273	475.4780711	474.9035822	2.092620759	4.37906164	2.804559233	-0.109868761	471.1537705	478.1768011
C ID 56	Perc%: 25%	0.25	474.8939492	468.8739632	481.2993273	475.5600711	474.9855822	2.092620759	4.37906164	2.804559233	-0.109868761	471.2357705	478.2588011
C ID 56	Perc%: 50%	0.5	474.9964492	468.9764632	481.4018273	475.6625711	475.0880822	2.092620759	4.37906164	2.804559233	-0.109868761	471.3382705	478.3613011
C ID 56	Perc%: 75%	0.75	475.0989492	469.0789632	481.5043273	475.7650711	475.1905822	2.092620759	4.37906164	2.804559233	-0.109868761	471.4407705	478.4638011
C ID 56	Perc%: 95%	0.95	475.1809492	469.1609632	481.5863273	475.8470711	475.2725822	2.092620759	4.37906164	2.804559233	-0.109868761	471.5227705	478.5458011
C ID 56	Perc%: 99%	0.99	475.1973492	469.1773632	481.6027273	475.8634711	475.2889822	2.092620759	4.37906164	2.804559233	-0.109868761	471.5391705	478.5622011
C ID 46	Perc%: 1%	8.37E-02	474.9288354	468.9684849	481.282769	475.923407	475.0505354	2.095945181	4.392986201	2.796403436	-0.101442262	471.3084211	478.2872761
C ID 46	Perc%: 5%	0.187082869	474.9433138	468.9829633	481.2972474	475.9378853	475.0650138	2.095945181	4.392986201	2.796403436	-0.101442262	471.3228994	478.3017545
C ID 46	Perc%: 25%	0.418330013	474.9756884	469.0153379	481.329622	475.9702599	475.0973884	2.095945181	4.392986201	2.796403436	-0.101442262	471.355274	478.3341291
C ID 46	Perc%: 50%	0.591607978	474.9999473	469.0395968	481.3538809	475.9945188	475.1216473	2.095945181	4.392986201	2.796403436	-0.101442262	471.379533	478.358388
C ID 46	Perc%: 75%	0.726138721	475.0187816	469.0584311	481.3727152	476.0133531	475.1404816	2.095945181	4.392986201	2.796403436	-0.101442262	471.3983673	478.3772223
C ID 46	Perc%: 95%	0.877525513	475.0399757	469.0796252	481.3939094	476.0345473	475.1616758	2.095945181	4.392986201	2.796403436	-0.101442262	471.4195614	478.3984165

Figure 7.11: Snapshot of sensitivity report presented in tabular form

7.3.8 Simulation result of case study 1, considering UK delay factors

This section presents the simulation results of case study 1 when considering the delay factors found from the UK industry survey. The aim is to identify the impact of delay factors in developed countries in order to test the first hypothesis of the research study, as set out in Chapter 1.

Case study 1 was run by incorporating the IW of delay factors (see Appendix D 2). The simulation results of case study 1 revealed that the minimum possible project duration of the building project was 454.74 days, that the maximum was 467.94 days, and that the mean was 461.32 days. It was found that the project was expected to be delayed by 88 days, compared to the planned duration of 373 days. The graphical results are shown in Figure 7.12. When comparing the results between two countries, it was found that the delay in the building project would be more in a developing country (Libya) than in a developed country (the UK).

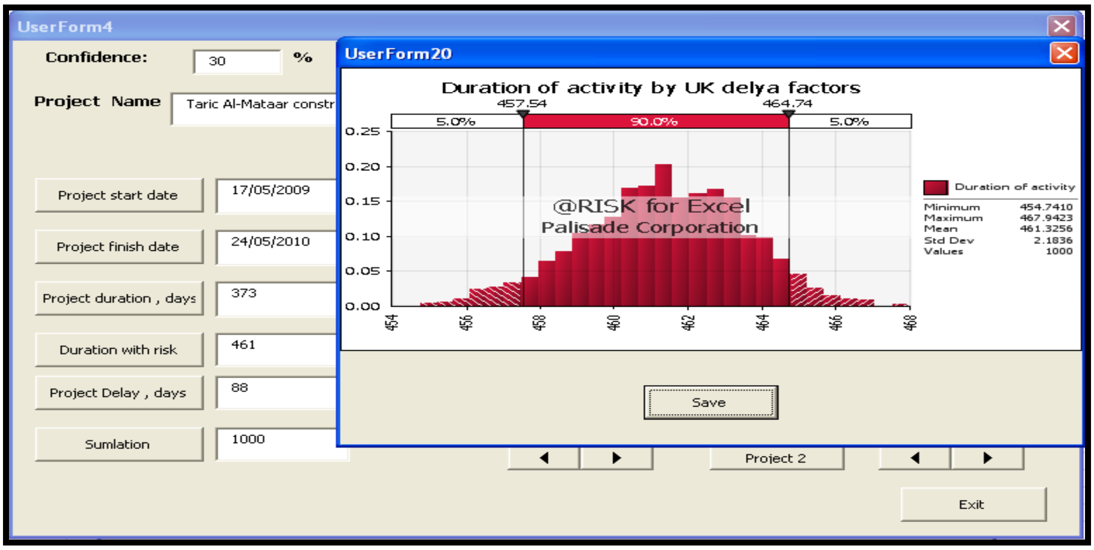


Figure 7.12: Snapshot of simulation results of case study 1, considering UK delay factors

7.3.9 Sensitivity reports of case study1, considering UK delay factors

The sensitivity report was also developed considering the critical delay factors found from the UK construction industry. Figure 7.13 mainly provides information in graph form about the possible duration of the project due to major delay factors that occurred.

The graphs show the variation in project durations due to the variation in positive and negative probability of each delay factor (from +100 % to 0 and 0 to – 100%). The sloping line is presented in different colours for different delay factors. If the slope is steep, then the delay factor is highly sensitive and the duration of the project varies highly between 0% and 100% of probability. For example, among all delay factors the delay factor ID no. 2 was found to be the most highly sensitive. The possible mean duration of the project varies from 469.84 to 470.09 days at 1% and 99% probability of the occurrence of the delay factors. This means that how the variation of each delay factor affects the project duration from the level of occurrence probability can be quantified, and such information used to take necessary measures aimed at reducing the impact of the delay factor in the project. Among other delay factors, the most critical delay factors were severe weather conditions on the job site, a shortage of required materials, poor economic conditions (currency, inflation rate, etc.), rises in the prices of material, changes in the scope of the project, and financial problems. The sensitivity report showed that severe weather conditions were the most sensitive factor (Figure 7.13). From the results, it was concluded that the sensitivity of delay factors was different in Libya and the UK.

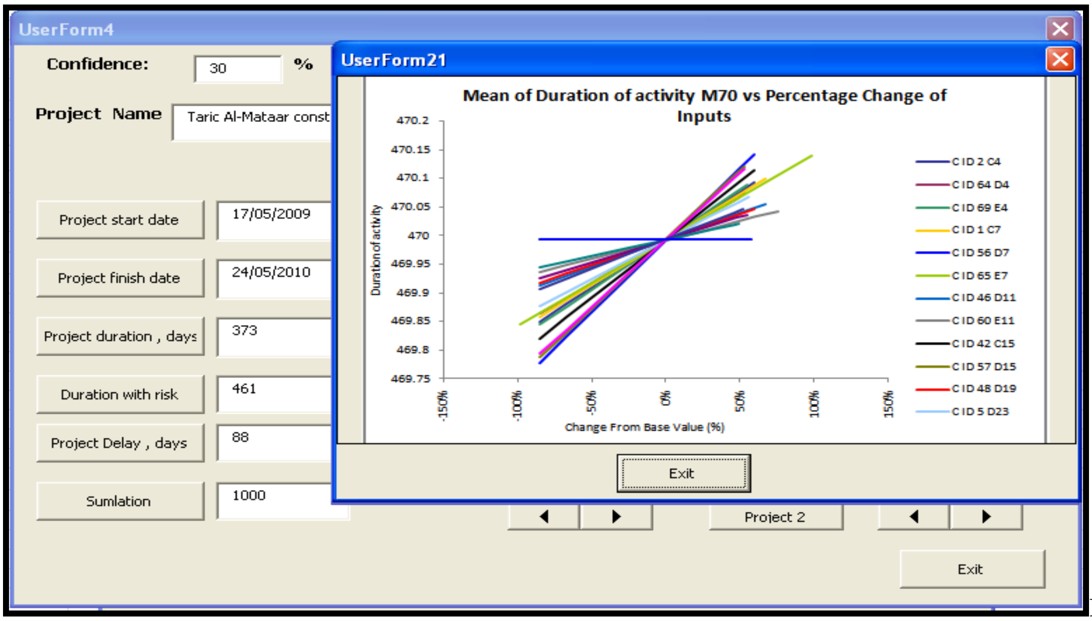


Figure 7.13: Sensitivity reports of the UK delay factors considered in case study 1

The sensitivity report provides different types of statistical information about the possible project duration, when considering each delay factor in the UK construction industry. The statistical information includes the Mean, Minimum, Maximum, Mode, Median, Standard Deviation, Variance, Kurtosis, Skewness, 5th Percentile and 95th Percentile of project duration (Figure 7.14). For example, in relation to the delay factor ID no. 2, the possible duration of the project has a different impact at different levels of probability (from 1%, 5%, 25%, 50%, 75%, 95% and 99%). In addition to these values, the sensitivity report also provides detailed information regarding the possible duration of the project at all probability levels. For example, at 50% probability level of occurrence, the mean duration of the project is 470.00 days, the minimum possible duration 464.28 days, and the maximum possible duration 475.16 days, with a standard deviation value of 1.96 in all these possible durations of the project when conceding the delay factor no. 2 (see Figure 7.14). Similarly, all critical delay factors were analysed to identify the sensitivity of each one in terms of possible project duration (with probability ranging from 1% to 99%; see Figure 7.14). The sensitivity report assists the project manager in understanding the gravity of each delay factor on the project duration at different levels of probability.

Advanced Sensitivity Analysis Summary Report

Performed By: g7132090
Date: 07 July 2011 11:34:25
Output: Duration of activity
Inputs Analyzed: 20
Simulations: 140

Input		Output: Duration of activity											
Name	Analysis	Value	Mean	Min	Max	Mode	Median	StdDev	Var	Kurtosis	Skewness	5%	95%
C ID 2	Perc%: 1%	8.94E-02	469.8498274	464.1366475	475.0093993	471.1604658	469.9343911	1.967126362	3.869586124	3.22286423	-0.209971973	466.4815278	473.081874
C ID 2	Perc%: 5%	0.2	469.8807834	464.1676036	475.0403553	471.1914218	469.9653472	1.967126362	3.869586124	3.22286423	-0.209971973	466.5124838	473.1128301
C ID 2	Perc%: 25%	0.447213595	469.9500033	464.2368234	475.1095752	471.2606416	470.034567	1.967126362	3.869586124	3.22286423	-0.209971973	466.5817036	473.1820499
C ID 2	Perc%: 50%	0.632455532	470.001871	464.2886911	475.1614429	471.3125094	470.0864347	1.967126362	3.869586124	3.22286423	-0.209971973	466.6335714	473.2339176
C ID 2	Perc%: 75%	0.774596669	470.0416705	464.3284906	475.2012424	471.3523089	470.1262343	1.967126362	3.869586124	3.22286423	-0.209971973	466.6733709	473.2737171
C ID 2	Perc%: 95%	0.9	470.0767834	464.3636036	475.2363553	471.3874218	470.1613472	1.967126362	3.869586124	3.22286423	-0.209971973	466.7084838	473.3088301
C ID 2	Perc%: 99%	0.95527864	470.0922615	464.3790816	475.2518334	471.4028999	470.1768252	1.967126362	3.869586124	3.22286423	-0.209971973	466.7239619	473.3243081
C ID 64	Perc%: 1%	0.094339811	469.8643174	464.1435571	475.1391509	470.4862091	469.9389435	1.973524296	3.894798147	3.208334504	-0.183945964	466.5731857	473.0390286
C ID 64	Perc%: 5%	0.210950231	469.8923039	464.1715436	475.1671374	470.5141956	469.96693	1.973524296	3.894798147	3.208334504	-0.183945964	466.6011722	473.0670151
C ID 64	Perc%: 25%	0.471699057	469.9548837	464.2341233	475.2297172	470.5767753	470.0295097	1.973524296	3.894798147	3.208334504	-0.183945964	466.663752	473.1295948
C ID 64	Perc%: 50%	0.667083203	470.0017759	464.2810155	475.2766094	470.6236675	470.0764019	1.973524296	3.894798147	3.208334504	-0.183945964	466.7106442	473.176487
C ID 64	Perc%: 75%	0.817006732	470.0377575	464.3169972	475.312591	470.6596491	470.1123836	1.973524296	3.894798147	3.208334504	-0.183945964	466.7466258	473.2124686
C ID 64	Perc%: 95%	0.925838015	470.063877	464.3431167	475.3387105	470.6857686	470.1385031	1.973524296	3.894798147	3.208334504	-0.183945964	466.7727453	473.2385881
C ID 64	Perc%: 99%	0.966833752	470.073716	464.3529557	475.3485495	470.6956076	470.1483421	1.973524296	3.894798147	3.208334504	-0.183945964	466.7825843	473.2484271
C ID 69	Perc%: 1%	0.092736185	469.8452414	464.0922903	475.0195748	470.4732153	469.9411936	1.969147742	3.87754283	3.266453813	-0.190011954	466.5601481	473.087369
C ID 69	Perc%: 5%	0.207364414	469.8773373	464.1243862	475.0516707	470.5053112	469.9732895	1.969147742	3.87754283	3.266453813	-0.190011954	466.592244	473.1194649
C ID 69	Perc%: 25%	0.463680925	469.949106	464.1961549	475.1234393	470.5770798	470.0450581	1.969147742	3.87754283	3.266453813	-0.190011954	466.6640126	473.1912335
C ID 69	Perc%: 50%	0.655743852	470.0028836	464.2499325	475.1772169	470.6308574	470.0988357	1.969147742	3.87754283	3.266453813	-0.190011954	466.7177903	473.2450112
C ID 69	Perc%: 75%	0.80311892	470.0441486	464.2911975	475.2184819	470.6721224	470.1401007	1.969147742	3.87754283	3.266453813	-0.190011954	466.7590553	473.2862762
C ID 69	Perc%: 95%	0.916333997	470.0758488	464.3228977	475.2501821	470.7038227	470.171801	1.969147742	3.87754283	3.266453813	-0.190011954	466.7907555	473.3179764
C ID 69	Perc%: 99%	0.962583426	470.0887987	464.3358476	475.263132	470.7167725	470.1847508	1.969147742	3.87754283	3.266453813	-0.190011954	466.8037053	473.3309262
C ID 1	Perc%: 1%	8.37E-02	469.8578191	464.1134412	475.0478807	471.0584537	469.9672163	1.964995174	3.861206036	3.213549952	-0.19572424	466.4964858	473.0540149
C ID 1	Perc%: 5%	0.187082869	469.8867758	464.142398	475.0768374	471.0874104	469.996173	1.964995174	3.861206036	3.213549952	-0.19572424	466.5254426	473.0829717

Figure 7.14: Snapshot of sensitivity report presented in tabular form considered UK factors in case study 1

The next section discusses the findings from the evaluation of case study 2, the educational and office building project in Libya.

7.4 Evaluation of DAS with case study 2

The evaluation of case study 2 is outlined in three sub-sections: collection of site information; processing of the input data; and presentation of the simulation results.

7.4.1 Collection of Site Information

At this stage, the construction schedule of the selected building project was collected from the construction company in Libya during a site meeting with the project team members. The project duration was found to be 332 days, with the starting date of 23/08/2004 and the finishing date of 29/11/2005. During the meeting, a list of critical activities of the project was identified and recorded for use as input data for the simulation model (see Appendix C-2).

As discussed in section 7.1.4, a list of potential delay factors associated with the building project was also listed at the site meeting. The information about the number of critical delay factors affecting each critical activity was identified and recorded from the construction professionals at the site meeting. Then, the influence values of each delay factor associated with the critical activities were calculated as discussed in the next section.

7.4.2 Calculation of influence value (risk factor)

This section explains the process of calculating the influence values (risk factors) of each delay factor associated with each critical activity of the building project. In this case study, a total of 25 critical activities were listed. Then, the delay factors associated with a critical activity (naming activity no 2) were demonstrated to show the calculation of influence value (see Table 7.4).

For example, waiting time for approval of drawings and sample, severe weather conditions, delays in delivering the site to the contractor, and inadequate equipment used for the works were identified as the main delay factors that affected critical activity number 2. The ID nos. of these delay factors are 69, 64, 43 and 8. The IWs of these delay factors were identified as 76.73, 65.27, 82.93 and 41.32 respectively through the industry survey (see Table 7.5). Then, the influence values of these delay factors (ID nos. 69, 64, 43 and 8) affecting the critical activity (ID no. 2), were identified as 0.29, 0.25, 31 and 0.16 respectively, as shown in Table 7.6, using the equation 5 (see Chapter 6). Similarly, the influence values of the three delay factors affecting the critical activities numbers 4, 5 and 6 were also identified, and are presented in Table 7.5 below. The influence values of the rest of the delay factors associated with the critical activities are shown in Appendix E1**.**

Table 7.5: Critical activity no. 2 with risk

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
2	69	Waiting time for approval of drawings	76.73	0.29
	64	Severe weather conditions on the site	65.27	0.25
	43	Delay in delivering the site to the contractor	82.93	0.31
	8	Inadequate equipment used for the works	41.32	0.16
			266.25	1.00

Table 7.6: Critical activities no. 4, 5 and 6 with delay and influence factors

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
4,5,6	60	Changes in the scope of the project	62.89	0.36
	10	Low skill of manpower	68.97	0.40
	8	Inadequate equipment used for the works	41.32	0.24
			173.19	1.00

7.4.3 Generation of random number

This section discusses the generation of a random number for each delay factor (risk factor). The types of distribution of each delay factor / risk factor were selected by the author according to the nature and impact level of the delay factors in case study 2. The generated random numbers using MCS and the influence values (risk factors) of each delay factor associated with each critical activity of the building project are shown in Appendix F-2.

7.4.4 Simulation results of case study 2

The simulation results from case study 2 showed that the minimum, maximum and mean possible project durations of the building project were 366.24, 377.38 and 372.49 days respectively. It was also found that the mean possible duration of the project (372.49 days) was more than the planned duration (332 days). This confirmed that the project could be delayed by 40.49 days when considering a total of 22 delay factors on the project.

7.4.5 Discussion of model results evaluation:

In case study-2, the model result of possible project duration was evaluated by comparing it to the actual duration of the project delivered (obtained from the consultant of the project). However, the comparison of actual duration of each activity of the project with the model-calculated duration was missing due to a lack of actual data. In this case study, the actual project duration (excluding holidays) was found to be 375 days when interviewing the supervision consultant of the project. When evaluating the possible duration estimated by the model, it was found that the project's actual delay was longer than expected by 2.51 days (375-372.49 days). This figure confirms that the model-calculated project duration considering the impact of delay factors is less than the actual duration of the project. Hence, it is concluded that the model is more reliable in quantifying the possible duration of a construction project and is a useful tool for analysing the impact of delay in a construction project. The detailed calculation and results obtained from the DAS are shown in Figure 7.15.

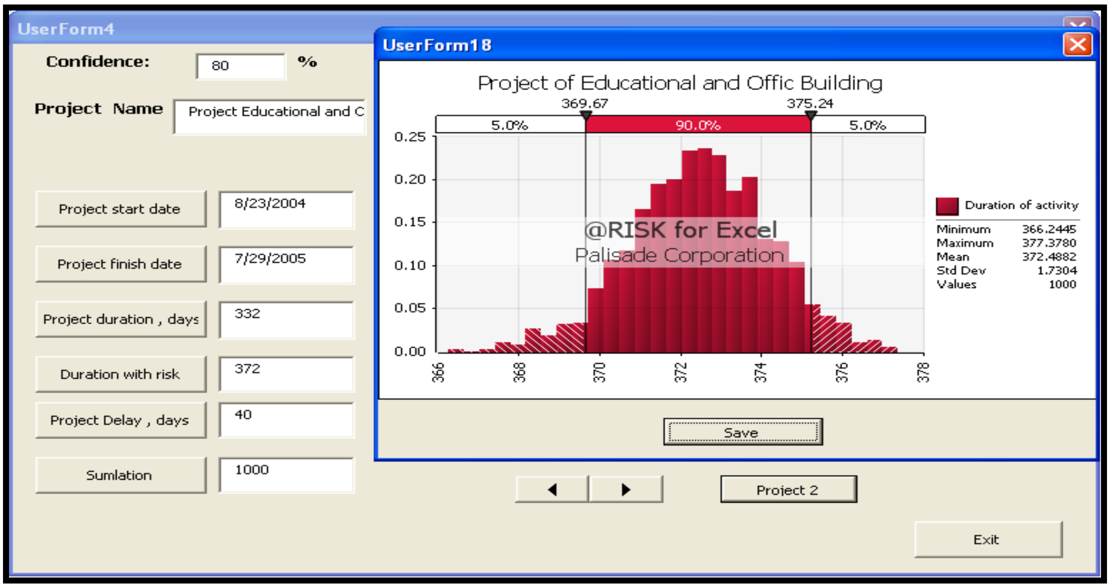


Figure 7.15: Simulation result of possible project duration from the case study 2 building project

7.4.6 Sensitivity reports of case study 2

Figure 7.16 provides information in graph form about the possible duration of the project due to major delay factors that occurred in the project. The graphs show the variation in project duration due to the variation in positive and negative probability of each delay factor (from +100 % to 0 and 0 to –100%). The sloping line is presented in different colours for different delay factors. If the slope is steep, then the delay factor is highly sensitive and the duration of the project varies highly between 0% and 100% of probability. This reveals how much sensitivity exists in each delay factor affecting the project and what the possible project duration is at each level of probability. This helps the project manager to take necessary measures to reduce the impact of delay factors in the project.

The major delay factors considered in analysing the project duration were the poor qualifications of the consultant engineer; severe weather conditions on the job site; waiting time for approval of drawings and test samples of materials; inadequate equipment used for the works; the low skills of the manpower; changes in the scope of the project; a shortage of required materials; delayed and slow supervision in making decisions; and poor communication between the consultant engineer and other parties. The graphical output of the sensitivity results of case study-2 is presented in Figure 7.16.

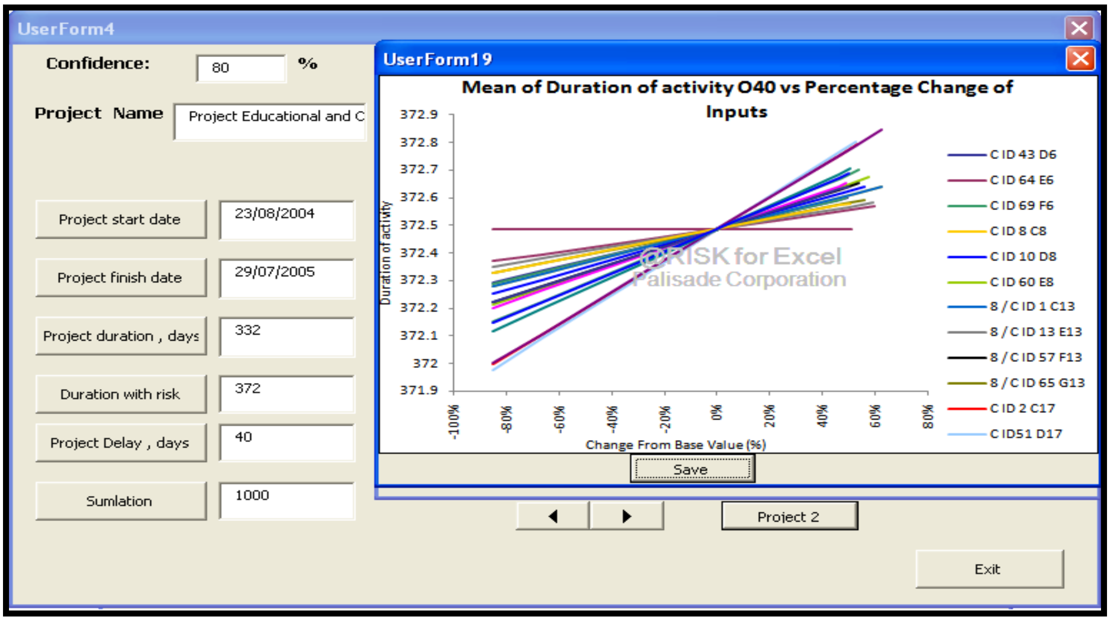


Figure 7.16: Report selection window for case study 2

7.4.7 Simulation result of case study 2, considering UK delay factors

Case study 2 was run again by considering the IW of delay factors that had been identified through the UK construction industry survey. The simulation results of case study 2 revealed that the minimum possible project duration of the building project was 360.06 days, that the maximum was 372.06 days, and that the mean was 366.77 days. As a result, the project might be delayed by 34 days compared to the planned duration (332 days) as shown in Figure 7.17. The influence values of the rest of the delay factors associated with the critical activities are shown in Appendix E 2.

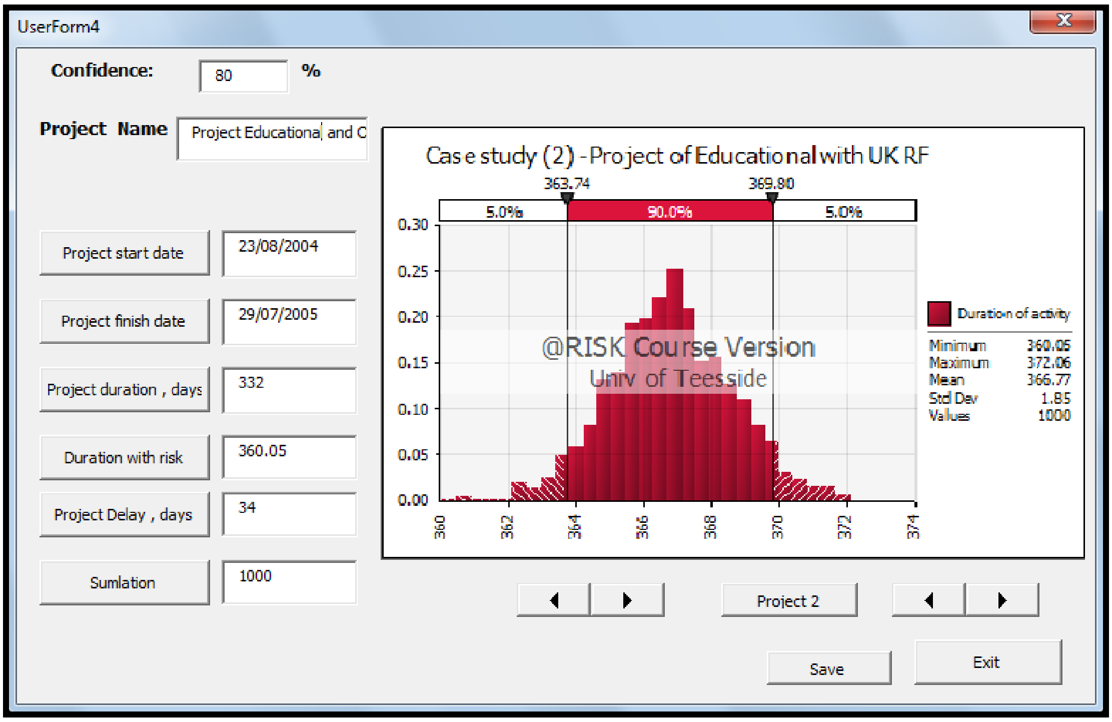


Figure 17: Snapshot of simulation results of case study 2, considering UK delay factors

7.4.8 Sensitivity reports of case study 2, considering UK delay factors

The sensitivity report was generated using the DAS in the case study -2 considering delay factors identified in the UK construction industry. The information about the possible duration of the project selected for case study-2 is shown in Figure 7.18 below, where the major delay factors were integrated and the sensitivity report presented in terms of a graph. The graph provides information on project duration at both the positive and negative probability of each delay factor (from +100 % to 0 and 0 to –100%). Each line shown in the figure represents a delay factor, and the sloping lines are presented in different colours for different delay factors. If the slope is steep, then the delay factor is considered highly sensitive; conversely, a shallow slope represents a less sensitive delay factor. The duration of the project varies between a 0% and 100% chance of probability occurrence. This shows how the variation of each delay factor affects the project duration from the level of probability, and what the possible duration is at each level of probability, in order to take necessary measures and reduce the impact of the delay factor in the project. The figure shows that the most critical delays factors are: delays in the preparation of drawings, delays in furnishing and delivering the site to the contractor, severe weather conditions on the job site, waiting time for the approval of drawings and test samples of materials, changes in the scope of the project, and financial problems.

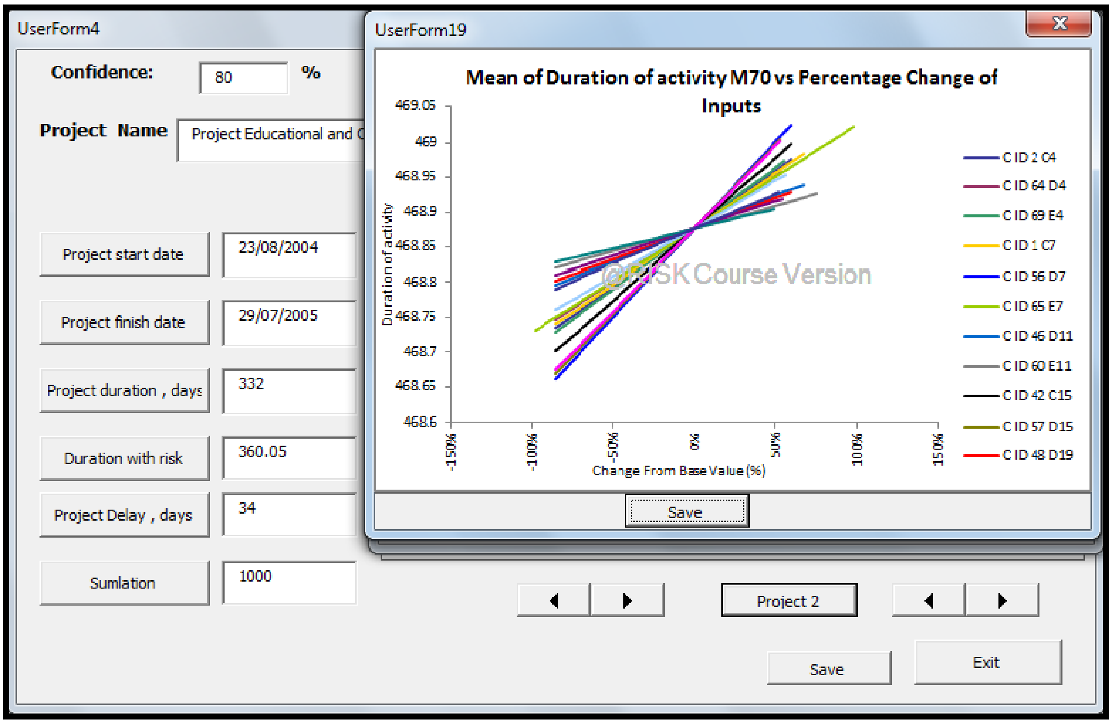


Figure 7.18: Sensitivity reports of the UK delay factors considered in case study 2

7.5 Summary of simulation result of case study1 and 2

The summary of both case studies' results is presented in Table 7.7. As explained previously, both case studies were selected from building projects in Libya but the IW of critical delay factors associated with building projects (identified from the industry surveys in Libya and the UK) were used to analyse and identify the possible project durations for both case studies, considering the impact of delay factors from both countries.

Table 7.7: Summary of case studies' results

Activities	Case study 1	Case study 2
Number of delay factors	24 delay factors	22 delay factors
Possible project delay considering the IW of delay factors found in Libyan construction projects	97 days	40 days
Possible project delay considering the IW of delay factors found in UK construction projects	88 days	34 days
Variation in project delay between Libya and the UK	9 days	6 days

The results presented in Table 7.7 proved that the impact in project duration due to delay factors associated with UK construction projects is less than the impact in project duration due to the delay factors associated with Libyan construction projects. Therefore, the author believes that the simulation model of the DAS can assist construction managers and project planners in investigating and analysing the possible risks associated with construction project delay factors before implementing the project. In turn, the model helps those stakeholders to take the necessary actions and measures to reduce the impact of delay factors associated with construction projects, to reschedule the project with the required resources, and to reallocate the risks throughout the construction project.

7.6 Chapter summary

This chapter presented the evaluation of the simulation model of the DAS using two case studies of building projects in Libya. The possible duration of the selected building projects was quantified by integrating the impact of delay factors associated with both building projects in Libya. At the same time, the project duration in both case studies was also evaluated using the influence values of delay factors identified from UK construction projects.

The case study 1 results showed that the building project might be delayed by 97 to 103 days from the planned duration when considering a total of 24 critical delay factors in Libyan construction projects. However, the same project might be delayed by 83 to 88 days when considering the influence of the delay factors in UK construction projects.

Similarly, the case study 2 results revealed that the building project might be delayed by 40 to 45 days from the planned duration when considering a total 22 critical delay factors in Libyan construction project. In contrast, the same project might be delayed by 34 to 39 days when considering the influence of the delay factors in a UK construction project. However, the delay in project duration might increase further when all listed delay factors are considered. The following points were highlighted from the findings of case studies, which were obtained using the simulation model of the delay analysis system:

- The developed system is competent for analysing and quantifying the possible project delay in building projects;
- It is easy to use if the proper training is provided to users;
- Knowledge incorporated into the system could be transferred to future projects;
- Reports produced by the system help stakeholders to understand the impact of delay factors in a construction project;
- The system is inexpensive since it works in MS Excel and has flexibility for further improvement by developing additional VBA programs.

Finally, it is concluded that the delay analysis system could be a decision support tool that helps stakeholders to analyse and quantify the impact of delay factors associated with a construction project and to take preventive measures to reduce the impact of those delay factors. The next chapter discusses the conclusions and recommendations from the study.

Chapter 8-

Conclusions and Recommendations

Chapter 8: Conclusions and Recommendations

8.1 Introduction

Previous chapters discussed the research methodology, literature review, construction industry survey, design of the conceptual framework of the delay analysis system (DAS) augmented with a simulation model, development of the simulation model of the DAS, and the evaluation of the developed model with case studies. The simulation model of the DAS was demonstrated with case studies from building projects in Libya, integrating the delay factors identified from the literature review and construction industry survey. This chapter presents the main conclusions drawn from the different chapters presented in this dissertation, and suggests recommendations for both further development and future study.

8.2 Conclusions of the research study

The conclusions drawn from the research study are summarised under different sections as follows: literature review; construction industry survey; research methodology for the development of the framework of the delay analysis system (DAS); and evaluation of the DAS using case studies of building projects in Libya.

8.2.1 Literature review

In this study, the first objective was set to identify the list of possible delay factors associated with construction projects, and to explore existing techniques being used to analyse those delay factors. In order to achieve the first objective, a comprehensive literature review was carried out, including research publications in journals, conference proceedings and related books. The following are the conclusions drawn from the literature review:

- Previous literature has shown that causes and effects of the delays in the construction industry can vary from country to country due to differences in the geographical locations, environmental constraints, and techniques applied in the construction processes;

- It was found that checklists, questionnaires, interviews with individuals or groups, brainstorming, and Delphi techniques are used as risk identification methodologies. Monte Carlo Simulation (MCS) is widely used to analyse the impact of possible risks associated with construction projects;
- The review of literature found that there was few research studies related to the identification of delay factors in the Libyan construction industry. However, there were no studies conducted on ranking the delay factors in the Libyan construction industry;
- A total of seventy five delay factors (internal and external) were found from the literature review as the most common delay factors in building construction projects, and these factors were included in the study to identify the Importance Weight (IW). For the purpose of analysis, these delay factors were classified into eight subcategories and four main categories related to owners, consultants, contractors, and external factors.

Finally, from the literature review, it was concluded that the Libyan construction industries have been facing various problems and challenges that may be attributed to delay factors because of the consequences of rapid social and economic change, an unstable operating environment, and technical and operational problems. However, other important factors are the lack of sufficient research studies into the construction industry, a lack of political, social and economic development strategies, and several administrative systems and state interventions. This satisfies the first objective of the study.

8.2.2 Construction industry survey

The second objective of the study was assigned to conducting a construction industry survey that aimed to identify the IW of each delay factor associated with Libyan construction projects, while the third objective was to rank the responsible parties (contractors, consultants, and owners) involved in construction projects in both Libya and the UK. In order to achieve the second and third objectives, a construction industry survey was conducted in both countries using questionnaires, with responses collected from consultants, contractors and owners in order to analyse the views of the parties involved. Importance Weight (IW) was calculated using frequency and severity index methods to rank the listed delay factors associated with construction projects, which helps to achieve the second objective of the study. The Important Index (II) and Average Weight (AW) methods were used to rank the responsible parties in construction projects, which achieve the third objective. The conclusions from the industry survey are as follows:

- The survey results showed that consultants, rather than contractors and owners, were the most responsible party for the delays in Libyan construction projects, whereas owners were the party most responsible for construction project delays in the UK;
- The identification of the responsible party will assist owners and clients in the decision-making process during the procurement of a public and private construction project;
- The survey results also found that the rank level of delay factors were different from the views of the three parties (contractors, consultants and owner) in both countries. The list of delay factors which were ranked considering IW is shown in Appendix B;
- The survey results showed that the five main delay factors in the Libyan construction industry were delays in materials delivery, a shortage of required equipment, the low skills of the manpower, waiting times for the approval of drawings and test materials, delays in issuing change orders by the owner, and poor qualifications of the consultant engineer's staff. In contrast, changes in materials prices, changes in the scope of the project, financial problems, severe weather conditions, and poor communication between the consultant engineer and the parties involved in the project were the most critical delay factors in the UK construction industry.

The statistical test results confirmed that there is a significant relationship between several delay factors, identified through the survey. The test results also confirmed that there is a significant relationship between the delay factors and the responsible parties associated with construction projects. The IW was identified and tested to be used as an input of the delay analysis system. This satisfies the second and third objectives of this research study.

8.2.3 Development of the framework of the delay analysis system

In order to achieve the fourth objective of this study, a framework of a delay analysis system (augmented with a simulation model) was developed. From the review of the literature and the construction industry survey, it was found that existing delay analysis techniques lacked the ability to integrate the influence of each delay factor with quantification of the delay impact in a construction project. Therefore, the delay analysis system was developed as a key methodology in this study to analyse and quantify the impact of possible risks (delay factors) in terms of time (duration) at the construction phase of building projects. The simulation model of the DAS was developed by integrating MS Excel with VBA macros and @risk simulator. The model has flexibility to produce different types of reports, including quantification of project delays and the sensitivity analysis of each delay factor associated with construction projects. The system is also flexible in providing the information in advance about possible project risk levels. The simulation model of the DAS was arranged under three parts: input, process and outputs:

- The list of critical delay factors, with the IW of each factor and the list of critical activities found in a project, are the key inputs of the system;

- The calculation of the influence values of each delay factor (which were calculated using the IW of delay factors), and the assignment of the number of delay factors to each critical activity (identified through the experience of construction professionals), are the initial processes of the delay analysis system. The generation of a random number, which is based on the selected risk distribution and generated using the Monte Carlo simulation technique and the determination of the possible duration of each critical activity (using equation developed by Dawood, 1998), are the key processes included in the simulation model of the DAS. The equation is capable of integrating the impact of each delay factor within the simulation model to predict the impact in duration of each activity and the whole project, considering the influence of each risk factor independently;

- The outputs of the DAS provide information about possible delays in a project, a list of critical delay factors, and the sensitivity of each delay factor that has a high impact on construction project delays.

It was concluded that the developed delay analysis system can assist project stakeholders in analysing and quantifying the impact of delay factors associated with construction projects in advance. Therefore, construction managers become capable of taking possible measures in the course of reducing the impact from delay factors in projects before they occur. The knowledge achieved through the system could also be utilised in future projects. This satisfies the fourth objective of this study.

8.2.4 Evaluation of the DAS with case studies

The fifth objective of the study was to evaluate the developed delay analysis system (augmented with a simulation model). In order to achieve the fifth objective, two case studies from building projects in Libya were selected as a means of evaluating the functions of the DAS. These case studies were used to analyse and quantify the impact of delay factors through the simulation model of the DAS. The following conclusions were drawn from the analysis of the case studies:

- Different types of delay factors caused minor to major delays in each activity of the projects. The lack of a proper delay analysis system caused the failure of the projects with loss in time;
- The construction industry might benefit from the simulation model of the DAS, as it helps to quantify the possible delay and provide information on the impact of delay factors in advance, enabling the project manager to take preventive measures to reduce the impact;
- The case study results showed that the building project might be delayed by 97-103 days in case study 1 or by 40-45 days in case study 2, when considering a total of 24 and 22 respective critical delay factors associated with Libyan construction projects. The difference in delay duration was found because of the

numbers of delay factors and the size of the projects in terms of project duration;

- The case study results also showed that the building projects might be delayed by 88-93 days in case study 1 and by 34-40 days in case study 2, when considering the IW of delay factors associated with UK construction projects;
- The results from the case studies proved that the impact of delays in developing countries like Libya is higher than in developed countries like the UK (satisfying the first hypothesis of this study).

Moreover, after demonstration through the case studies, the following points about the function of the simulation model of the DAS can be highlighted:

- The knowledge incorporated in the system (about how to integrate the IW and critical activities to identify the impact of delay factors in a project) could be transferred to future building construction projects;
- Reports produced by the simulation model of the DAS assist project managers in their understanding and management of the risks associated with building construction projects;
- The developed system is simple in terms of operation since it works in the existing MS environment and can be improved further by integrating additional VBA macros within the system;
- The developed delay analysis system tool (augmented with a simulation model) is a possible solution for analysing the impact of delay factors in building construction projects (satisfying the second hypothesis of the study).

Finally, it is concluded that the simulation model of the DAS, developed during the course of this study, is a tool to analyse and quantify the impact of delay factors (risks) associated with building construction projects. This satisfies the fifth objective of this study.

8.3 Research contribution to knowledge/significance

The key contribution of this study is development of a strategy (delay analysis system) for analysing the impact of delay factors in the Libyan construction industry through better investigated, understood and documented reports. The system is expected to help policymakers, decision-makers and others stakeholders within the construction industry to gain a fuller understanding of the industry. This will enable them to make efficient decisions to formulate short- and long-term construction strategies and policies that aim to improve the industry's processes and operations. Additionally, there are five other key contributions which make this study significant:

1. The study fills a gap in knowledge relating to analysis of construction delay in the Libyan construction industry, and introduces a systematic document for research purposes in the field of the construction industry, particularly in developing countries. For example, in the case of Libya, there is little previous research study in the field of delay analysis, particularly in the construction industry.

2. The study helps to make government departments and decision-makers aware of the significance of delays in construction projects in terms of economic growth and the development processes. Since the study provides a methodology to understand delay factors and to quantify the impact of possible delay in construction in advance, this certainly assists decision-makers in public departments in taking proactive measures to reduce the possible delay impact.

3. A delay analysis system was created from the study to analyse and quantify the duration of delays, considering the impact of associated delay factors independently in construction projects. The system developed in the study is a new methodology in terms of integrating the influence factors with critical activities to quantify the impact of delay factors and provide in-depth understanding of delay factors.

4. The outcomes of the research study provide a new methodology for construction practitioners and researchers, as well as delivering a decision-support system for

taking proactive measures to reduce the impact of delay in building construction projects, particularly in developing countries like Libya.

8.4 Recommendations

This section discusses the recommendations for identifying, analysing and responding to the delay factors associated with building construction projects. Taking into account the findings from the literature review and industry survey, and the results obtained from the case studies of building projects in Libya using the simulation model of the DAS, the following recommendations are suggested to manage the delay risks associated with construction projects. The recommendations and solutions suggested by construction professionals during the review of the case studies were also taken into account in developing the following recommendations. These recommendations are presented in four categories: owners, contractors, consultants, and external factors.

8.4.1 Owners should consider the following recommendations:

- Pay progress payments regularly to contractors so that delays can be avoided, and the contractor's ability to deliver the project on time and within quality improved;
- Minimise change orders throughout construction to avoid delays to the project;
- Review and approve the design documents within the agreed schedule;
- Verify the resources and capabilities of the lowest bidding contractors before awarding the contract.

8.4.2 Contractors should consider the following recommendations:

- The required amount of manpower should be allocated to the construction site, and site productivity should be improved by mobilising all resources;
- The contractor should manage financial resources and plan cash flow by utilising progress payments and managing the contingency budget to cover expenses resulting from climate factors and high market prices;
- To avoid cost overrun and disputes, contractors need to focus on planning and scheduling tasks during the construction process by matching the available resources and time;
- Site administrative and technical staff should be assigned as soon as the project is awarded, so that the project can be delivered within the specified time, to the required quality, and to the estimated cost;
- To improve contractors' managerial skills, there is a need for continuous work-training programmes for personnel in the industry, so that they can update their knowledge and become familiar with project management skills;
- Motivate to improve workers' skills by awarding pay rises;
- Avoid reworks at site, since they reduce the morale of foremen and workers, causing further delays;
- Contractors should plan effectively for the delivery of materials and equipment in time to avoid expected delays from late delivery during construction.

8.4.3 Consultants should focus on the following points:

- Reviewing and approving design documents: any delay caused by the consultant engineer in checking, reviewing and approving the design submittals prior to the construction phase could delay the progress of the project work;
- Inflexibility: Consultants should be flexible in evaluating contractor works without compromising the quality of works;
- Approve design documents: Working drawings and construction schedules need to be approved in time to avoid work suffering from delays or quality issues;

- Inspection of mistakes and discrepancies in design documents: These are common reasons for redoing designs and drawings, and it may take a long time to make necessary corrections;
- Communication and coordination: Consultants need to make sure that there is proper communication and coordination among project stakeholders to avoid delays due to a lack of proper communications at the construction site;
- Testing materials: Facilitating the laboratory testing of construction materials and products is crucial to avoid construction project delays and reworks.

8.4.4 The following recommendations are suggested to manage external factors:

- To avoid time extensions due to adverse weather, it is recommended to improve site productivity by working overtime hours or to work night shifts when weather allows;
- To overcome delays due to unexpected variations in site conditions, there is need for more resources, a number of different sets of equipment, and the availability of skilled manpower;
- To avoid damages and loss from unexpected war or natural disasters, or delays due to changes in governmental rules and regulations, construction projects – including their equipment, manpower and materials – need to be insured with a reliable insurance company.

8.5 Future research studies

1. The developed delay analysis system has flexibility to incorporate further improvements that could maximise the benefits of the system.

2. The system may be further improved by adding more options of risk distribution patterns in solving the problem of risk factors.

3. The next improvement would be linking the system with a cost estimation software package that would allow costing of the risks. This would help to achieve accurate results of risk management associated with project costing.

4. The system can be improved by running different types of construction projects (i.e. other than building projects) to improve the effectiveness of the system.

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Appendix-A
Questionnaire sample with consent letter

a) Consent letter

Dear Sir or Madam:

Subject: Survey

I am conducting a research project with the aim to investigate a new methodology for analysing and quantifying the impacts of delay factors on construction projects.

The objective of this questionnaire is to identify the factors responsible for project delay and solutions for the causes of delay in the Libyan construction industry.
Please find a questionnaire attached herewith and I kindly request you to spare part of your valuable time to fill the questionnaire.

Please note that your name and your company or department name will remain confidential when analysing the questionnaire. The collected data will be statistically analysed, and conclusions will be drawn that will assist the Libyan in construction project to minimise project delays.

If you wish, I shall be happy to provide you with the results of the study once finished. Your assistance and cooperation will be highly appreciated. Please ignore this question if you feel that you are not enough position in answer the questions.

Thank you,

Please return your response to following address:

32 Park Vale Road
Middleborough
Tees Valley, TS1 3HW, UK

b) Questionnaire Sample

Please respond to the following questions either by ticking the appropriate box or by writing your answer in the space provided. Please note:

1. The answers should be based on your experience in construction projects.
2. All information provided will be treated in the strictest of confidence.

Section one – ***Questions related to the respondent's experience.***

1.1. What is your type of business?

- ○ Contractor
- ○ Owner
- ○ Consultant
- ○ Client/ Client representative
- ○ Other please specify ____________________

1.2. What are the organization being involved?

- ○ Public
- ○ Private
- ○ Both

1.3. How long have you been involved in the construction projects?

- ○ <5 years
- ○ 6-10 years
- ○ 11-15 years
- ○ >16 years

1.4. What is your specialization in building construction? (You might select more than one)

- ○ Commercial buildings
- ○ Industrial buildings
- ○ Governmental buildings
- ○ Residential Buildings
- ○ Other please specify ______________________________________

1.5. What is the value of the current project you are involved?

- ○ Over 30 million
- ○ £ 16 – 30 million
- ○ £ 5 – 15 million
- ○ Under £5 million

1.6. What is the value of the current project you are involved? (You might select more than one)

- ○ Very large
- ○ Large
- ○ Medium
- ○ Small

Section two – ***Questions related to the performance of projects you have been involved in.***

2.1. How many construction project have you been participated in?
Please specify ________

2.2. Was one or more of them delayed??
- ○ Yes
- ○ No

If the answer to question 2.2 is NO please go to question 2.6

2.3. How many of them were delayed?
Please specify ________

2.4. What percentage of you projects finishes late?
- ○ Less than 10%
- ○ 10 to 30 %
- ○ 31 to 50 %
- ○ 51 to 100%
- ○ Over 100 % please specify ___________________

2.5. What is the average of delayed time that was authorised by owners?
- ○ All the delayed time
- ○ About 75% of delayed time
- ○ About 50 % of delayed time
- ○ About 25% of delayed time
- ○ The contractor paid the liquidated damages for all delayed time

2.6. What are the procurement methods have you dealt with? (You might select more than one)
- ○ Traditional
- ○ Management contracting
- ○ Design and build
- ○ Construction management
- ○ Other please specify ____

2.7. What are the tendering arrangements have you been experienced? (You might select more than one)
- ○ Negotiation
- ○ Open tendering
- ○ Selective tendering
- ○ Two-stage selective tendering
- ○ Serial or contentious please specify _______________________________

2.8. Who is the most responsible side for construction delays?
- ○ Contractor
- ○ Consultant
- ○ Owner
- ○ Other

Section three – ***delay factors***

3. Please specify the most important 5 delay factors of construction projects?
(See the delay factors in section three)

1. ____
2. ____
3. ____
4. ____
5. ____

3.1. Rank the delay factors below to their frequency and severity weight.

Scale	Frequency	Severity
1	Never	No effect
2	Occasionally	Fairly severe
3	Frequently	Severe
4	Constantly	Very severe

Delay factors	**Frequency**				**Severity**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
➢ ***Materials***								
1. Shortage of required materials	○	○	○	○	○	○	○	○
2. Delay in materials delivery	○	○	○	○	○	○	○	○
3. Changes in materials prices	○	○	○	○	○	○	○	○
4. Changes in materials specifications	○	○	○	○	○	○	○	○
➢ ***Equipment***								
5. Shortage of required equipment	○	○	○	○	○	○	○	○
6. Failure of equipment	○	○	○	○	○	○	○	○
7. Shortage of supporting and shoring installations for excavations	○	○	○	○	○	○	○	○
8. Inadequate equipment used for the works	○	○	○	○	○	○	○	○
➢ ***Manpower***								
9. Shortage of manpower (skilled, semi-skilled, unskilled labour)	○	○	○	○	○	○	○	○
10. Low skill of manpower	○	○	○	○	○	○	○	○
➢ ***Project Management***								
11. Lack of motivation among contractor’s members	○	○	○	○	○	○	○	○
12. Shortage of contractor’s administrative personnel	○	○	○	○	○	○	○	○

13. Shortage of technical professionals in the contractor's organization	○ ○ ○ ○	○ ○ ○ ○
14. Poor communications by the contractor with the parties involved in the project	○ ○ ○ ○	○ ○ ○ ○
15. Contractor's poor coordination with the parties involved in the project	○ ○ ○ ○	○ ○ ○ ○
16. Slow preparation of changed orders requested by the contractor	○ ○ ○ ○	○ ○ ○ ○
17. Ineffective contractor head office involvement in the project	○ ○ ○ ○	○ ○ ○ ○
18. Delays in mobilization	○ ○ ○ ○	○ ○ ○ ○
19. Poor controlling of subcontractors by contractor	○ ○ ○ ○	○ ○ ○ ○
20. Loose safety rules and regulations within the contractor's organization	○ ○ ○ ○	○ ○ ○ ○
21. Poor qualifications of the contractor's assigned to the project	○ ○ ○ ○	○ ○ ○ ○
22. Improper technical studies by the contractor during the bidding stage	○ ○ ○ ○	○ ○ ○ ○
23. Ineffective planning and scheduling of the project by the contractor	○ ○ ○ ○	○ ○ ○ ○
24. Delays to field survey by the contractor	○ ○ ○ ○	○ ○ ○ ○
25. Ineffective control of project progress by the contractor	○ ○ ○ ○	○ ○ ○ ○
26. Inefficient quality control by the contractor	○ ○ ○ ○	○ ○ ○ ○
27. Delay in the preparation of contractor document submissions	○ ○ ○ ○	○ ○ ○ ○
28. Improper construction methods implemented by the contractor	○ ○ ○ ○	○ ○ ○ ○
29. Difficulties in financing project by contractor	○ ○ ○ ○	○ ○ ○ ○
30. Poor communication and coordination by contractor with other parties	○ ○ ○ ○	○ ○ ○ ○
31. Delays in sub-contractors work	○ ○ ○ ○	○ ○ ○ ○
32. Problems between the contractor and his subcontractors with regard to payments	○ ○ ○ ○	○ ○ ○ ○
33. Poor qualification of the contractor's technical staff	○ ○ ○ ○	○ ○ ○ ○
34. Poor site management and supervision by contractor	○ ○ ○ ○	○ ○ ○ ○
35. Rework due to errors activities during construction	○ ○ ○ ○	○ ○ ○ ○
➢ **Owner**	○ ○ ○ ○	○ ○ ○ ○
36. Lack of experience of owner in construction	○ ○ ○ ○	○ ○ ○ ○
37. Improper project feasibility study	○ ○ ○ ○	○ ○ ○ ○
38. Lack of working knowledge	○ ○ ○ ○	○ ○ ○ ○
39. Slowness in making decisions	○ ○ ○ ○	○ ○ ○ ○
40. Lack of coordination with contractors	○ ○ ○ ○	○ ○ ○ ○
41. Contract modifications (replacement and addition of new work to the project and change in specifications)	○ ○ ○ ○	○ ○ ○ ○

42. Financial problems (delayed payments, financial difficulties, and economic problems)	○ ○ ○ ○	○ ○ ○ ○
43. Delay in furnishing and delivering the site to the contractor by the owner	○ ○ ○ ○	○ ○ ○ ○
44. Unrealistic contract duration	○ ○ ○ ○	○ ○ ○ ○
45. Delay in the settlement of contractor claims by the owner	○ ○ ○ ○	○ ○ ○ ○
46. Delay in issuing of change orders by the owner	○ ○ ○ ○	○ ○ ○ ○
47. Slow decision making by the owner organisation	○ ○ ○ ○	○ ○ ○ ○
48. Interference by the owner in the construction operations	○ ○ ○ ○	○ ○ ○ ○
49. Delay in progress payments by the owner	○ ○ ○ ○	○ ○ ○ ○
➢ **Consultant**		
50. Poor qualification of consultant engineer's staff assigned to the project	○ ○ ○ ○	○ ○ ○ ○
51. Delay in the preparation of drawings	○ ○ ○ ○	○ ○ ○ ○
52. Delay in the approval of contractor submissions by the consultant	○ ○ ○ ○	○ ○ ○ ○
53. Poor design and delays in design	○ ○ ○ ○	○ ○ ○ ○
54. Slow response and poor inspection	○ ○ ○ ○	○ ○ ○ ○
55. Absence of consultant's site staff	○ ○ ○ ○	○ ○ ○ ○
56. Delayed and slow supervision in making decisions	○ ○ ○ ○	○ ○ ○ ○
57. Incomplete documents	○ ○ ○ ○	○ ○ ○ ○
58. Slowness in giving instruction	○ ○ ○ ○	○ ○ ○ ○
59. Poor communication between the consultant engineer and other parties	○ ○ ○ ○	○ ○ ○ ○
➢ **Early Planning and design**		
60. Changes in the scope of the project	○ ○ ○ ○	○ ○ ○ ○
61. Ambiguities, mistakes, and inconsistencies in specifications and drawings	○ ○ ○ ○	○ ○ ○ ○
62. Subsurface site conditions materially differing from contract documents	○ ○ ○ ○	○ ○ ○ ○
63. Original contract duration is too short	○ ○ ○ ○	○ ○ ○ ○
➢ **External Factors**		
64. Severe weather conditions on the job site	○ ○ ○ ○	○ ○ ○ ○
65. Rise in the prices of materials	○ ○ ○ ○	○ ○ ○ ○
66. Lack of equipment and tools on the market	○ ○ ○ ○	○ ○ ○ ○
67. Poor site conditions (location, ground, etc.)	○ ○ ○ ○	○ ○ ○ ○
68. Poor economic conditions (currency, inflation rate, etc.)	○ ○ ○ ○	○ ○ ○ ○
69. waiting time for approval of drawings and test samples of	○ ○ ○ ○	○ ○ ○ ○

materials,		
70. External work due to public agencies (roads, utilities and public services).	○ ○ ○ ○	○ ○ ○ ○
71. Problem with Neighbours	○ ○ ○ ○	○ ○ ○ ○
72. Unexpected geological condition	○ ○ ○ ○	○ ○ ○ ○
73. Slow Site Clearance	○ ○ ○ ○	○ ○ ○ ○
74. Unstable laws and regulation	○ ○ ○ ○	○ ○ ○ ○
75. Rework due to errors during construction	○ ○ ○ ○	○ ○ ○ ○

Comments:

Thank you very much; your response is highly appreciated.

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Appendix-B1:

Calculation of Importance Weight (IW) and ranking tables

This appendix includes the illustration of IW calculation and ranking tables. The lusted of delay factors identified from construction industry survey in both Libya and the UK.

Illustration of IW calculation of a delay factor:

To illustrate, a delay factor ID no 2 from contactor was selected and IW was calculated as follows:

$$(\text{F.I.})(\%) = \sum_{a=1}^{4} \text{a}(\text{n}/\text{N}) * 100/4$$

= [1(2/24) + 2(2/24) + 3(9/24) + 4(11/24)] * 25

= [0.08 + 0.16 + 1.12 + 1.83] *25

= 3.20 * 25 = 80.20

$$(\text{S.I.})(\%) = \sum_{a=1}^{4} \text{a}(\text{n}/\text{N}) * 100/4$$

= [1(1/24) + 2(2/24) + 3(7/24) + 4(15/24)] * 25

= [0.04 + 0.16 + 0.87 + 2.5] *25

= 3.58 * 25 = 89.58

$$\text{IW} = [\text{F.I.}(\%) * \text{S.I.}(\%)]\ /100$$

= (80.20 * 89.58)/ 100 = 71.84

Similarly, IW of all delay factors were calculated and presented in table below.

a) Ranking of delay factors identified in Libyan construction projects from contractors aspects						
No	**List of Delays Factors**	**Ctg**	**IW**	**R**	**II**	**Rank**
2	Delay in materials delivery	C/TM	71.84	24	2.894	1
10	Low skill of manpower	C/MP	62.50	24	2.604	2
69	Waiting time for approval drawings and test samples of materials	EF	60.22	24	2.509	3
70	External work due to public agencies(roads, and public services	EF	58.62	24	2.443	4
75	Rework due to errors during construction	EF	57.82	24	2.409	5
5	Shortage of required equipment	C/EQ	57.83	24	2.408	6
1	Shortage of required materials	C/MT	57.01	24	2.375	7
64	Severe weather conditions on the job site	EF	53.93	24	2.247	8
65	Rise in the prices of materials	EF	52.28	24	2.178	9
61	Ambiguities, mistakes, and inconsistencies of drawing	EP	47.66	24	1.986	10
13	Shortage of technical professionals in contractor’s organization	C/PM	46.99	24	1.958	11
35	Rework due to errors activities during construction the project	C/PM	46.98	24	1.957	12
22	Improper technical studies by contractor during the bidding stage	C/PM	46.42	24	1.934	13
68	Poor economic conditions, (currency, inflation rate, est.)	EF	46.34	24	1.931	14
31	Delay in sub-contractor work	C/PM	46.33	24	1.930	15
74	Unstable laws and regulation	EF	46.20	24	1.925	16
28	Improper construction methods implemented by the contractor	C/PM	44.41	24	1.850	17
32	Problems between the contractor and his subcontractors	C/PM	43.43	24	1.810	18
12	Shortage of contractor’s administrative personnel	C/PM	39.50	24	1.646	19
20	Loose safety rules and regulations within contractor’s organization	C/PM	38.41	24	1.600	20
7	Shortage of supporting and shoring installations for excavations	C/EQ	37.75	24	1.573	21
29	Difficulties in financing the project by the contractor	C/PM	37.60	24	1.567	22
34	Poor site management and supervision by contractor	C/PM	37.43	24	1.560	23
23	Ineffective planning and scheduling of the project by contractor	C/PM	37.13	24	1.547	24
67	Poor site conditions (location, ground, etc)	EF	35.49	24	1.520	25
4	Changes in materials specifications	C/MT	35.21	24	1.467	26
16	Slow preparations of change orders required	C/PM	34.64	24	1.443	27
60	Changes in the scope of the project	EP	33.85	24	1.410	28
25	Ineffective control of project progress by the contractor	C/PM	33.15	24	1.381	29
24	Delays to field survey by the contractor	C/PM	32.82	24	1.368	30
62	Subsurface site conditions differing from contract document	EP	32.23	24	1.343	31
15	Contractor 's poor coordination with other parties in project	C/PM	32.22	24	1.341	32
14	Poor communication between contractor with other parties	C/PM	32.21	24	1.340	33
27	Delay in the preparation of contractor submission	C/PM	31.05	24	1.294	34
3	Changes in materials prices	C/MT	30.47	24	1.270	35
11	Lack of motivation of contractor's members	C/PM	29.91	24	1.246	36
17	Ineffective contractor head office involvement in the project	C/PM	29.17	24	1.215	37
8	Inadequate equipment used for the works	C/EQ	28.46	24	1.186	38
63	Original contract duration is too short	EP	24.99	24	1.041	39
66	Lack of equipment and tools on the market	EF	23.41	24	0.975	40
26	Inefficient quality control by the contractor	C/PM	22.95	24	0.956	41
21	Poor qualifications of contractor’s staff assigned to the project	C/PM	21.88	24	0.912	42
9	Shortage of manpower (skilled, semi-skilled, unskilled labour)	C/MP	19.57	24	0.815	43
27	Delay in the preparation of contractor submission	C/PM	19.05	24	0.794	44
19	Poor controlling of subcontractors by contractor	C/PM	19.04	24	0.793	45

b) Ranking of delay factors identified in Libyan construction projects from consultants aspects						
No	**List of Delays Factors**	**Ctg**	**IW**	**R**	**II**	**Rank**
50	Poor qualification of consultant engineer’s staff	CNS	90.25	20	4.513	1
3	Changes in materials prices	MT	90.23	20	4.332	2
60	Changes in the scope of the project	EP	86.63	20	4.523	3
69	Waiting time for approval of drawings and test of materials	EF	85.52	20	4.275	4
56	Delayed and slow supervision in making decisions	CNS	84.41	20	4.221	5
52	Delay in the approval of consultant submissions by the consultant	CNS	83.24	20	4.163	6
57	Poor planning and incomplete contract documents	CNS	83.2	20	4.16	7
9	Shortage of manpower (skilled, semi-skilled, unskilled labour)	PM	73.24	20	3.662	8
61	Ambiguities, mistakes, and inconsistencies of drawings	EP	72.63	20	3.651	9
10	Low skill of manpower	PM	72.11	20	3.605	10
51	Delay in the preparation of drawings	CNS	72.03	20	2.982	11
8	Inadequate equipment used for the works	EQ	68.06	20	3.403	12
54	Slow response and poor inspection	CNS	66.02	20	3.301	13
53	Poor design and delays in design	CNS	63.85	20	3.193	14
63	Original contract duration is too short	EP	63.75	20	3.187	15
58	Slowness in giving instruction	CNS	63.00	20	3.150	16
64	Severe weather conditions on the job site	EF	62.97	20	3.148	17
65	Rise in the prices of materials	EF	62.00	20	3.100	18
75	Rework due to errors during construction	EF	54.25	20	2.713	19
55	Absence of consultant’s site staff	CNS	50.63	20	2.531	20
4	Changes in materials specifications	MT	49.79	20	2.489	21
1	Shortage of required materials	MT	49.00	20	2.450	22
6	Failure of equipment	EQ	48.00	20	2.430	23
62	Subsurface site conditions materially differing from contract	EP	44.53	20	2.226	24
5	Shortage of required equipment	EQ	43.64	20	2.182	25
67	Poor site conditions (location, ground, etc.)	EF	39.84	20	1.992	26
70	External work due to public agencies (roads, and public services	EF	36.56	20	1.828	27
74	Unstable laws and regulation	EF	35.94	20	1.797	28
66	Lack of equipment and tools on the market	EF	33.00	20	1.650	29
73	Slow site clearance	EF	32.67	20	1.633	30
59	Poor communication between the consultant and other parties	CNS	32.65	20	1.632	31
7	Shortage of supporting and shoring installations for excavations	EQ	32.62	20	1.623	32
68	Poor economic conditions (currency, inflation rate, etc.)	EF	32.59	20	1.621	33

c)Ranking of delay factors identified in Libyan construction projects from owners aspects						
No	**List of Delays Factors**	**Ctg**	**IW**	**R**	**II**	**Rank**
9	Shortage of manpower (skilled and unskilled labour)	MP	95.58	28	3.414	1
45	Delay in the settlement of contractor claims by the owner	OWN	88.73	28	3.169	2
69	Waiting time for approval of drawings and test materials	EF	84.45	28	3.016	3
46	Delay in issuing of change orders by the owner	OWN	84.45	28	2.031	4
43	Delay to delivering the site to the contractor by owner	OWN	82.93	28	2.962	5
41	Contract modifications (replacement and addition of new work)	OWN	82.03	28	2.93	6
2	Delay in materials delivery	MT	81.31	28	2.904	7
64	Severe weather conditions on the job site	EF	78.91	28	2.818	8
48	Interference by the owner in the construction operations	OWN	74.98	28	2.678	9
42	Financial problems (delayed payments, and economic problems)	OWN	74.08	28	2.646	10
10	Low skill of manpower	MP	72.31	28	2.588	11
60	Changes in the scope of the project	EP	68.19	28	2.435	12
70	External work due to public agencies (roads, public services)	EF	67.47	28	2.41	13
36	Lack of experience of owner in construction	OWN	65.37	28	2.334	14
65	Rise in the prices of materials	EF	64.5	28	2.304	15
1	Shortage of required materials	MT	63.80	28	2.279	16
61	Ambiguities, mistakes, and inconsistencies of drawings	EP	62.28	28	2.224	17
7	Shortage of supporting and shoring from the consultants	EQ	59.55	28	2.127	18
40	Lack of coordination with contractors	OWN	57.59	28	2.057	19
4	Changes in materials specifications	MT	54.89	28	1.960	20
47	Slow decision making by the owner organisation	OWN	53.59	28	1.914	21
44	Unrealistic contract duration	OWN	44.83	28	1.601	22
68	Poor economic conditions (currency, inflation rate, etc.)	EF	41.92	28	1.496	23
37	Improper project feasibility study	OWN	39.99	28	1.428	24
49	Delay in progress payments by the owner	OWN	38.41	28	1.372	25
66	Lack of equipment and tools on the market	EF	37.82	28	1.351	26
5	Shortage of required equipment	EQ	35.24	28	1.259	27
39	Slowness in making decisions	OWN	30.61	28	1.093	28
3	Changes in materials prices	MT	29.59	28	1.057	29
38	Lack of working knowledge	OWN	29.55	28	1.055	30
6	Failure of equipment	EQ	29.53	28	1.054	31
74	Unstable laws and regulation	EF	27.46	28	0.981	32
8	Inadequate equipment used the works	EQ	27.45	28	0.980	33
67	Poor site conditions (location, ground, etc.)	EP	25.41	28	0.977	34
73	Slow site clearance	EF	25.41	28	0.975	35

d) Ranking of delay factors identified in UK construction projects from contractors aspects						
No	**List of Delays Factors**	**Ctg**	**IW**	**R**	**II**	**Rank**
3	Changes in materials prices	C/MT	62.20	13	4.785	1
60	Changes in the scope of the project	EP	58.13	13	4.472	2
32	Problems between the contractor and his subcontractors	C/PM	55.13	13	4.241	3
64	Severe weather conditions on the job site	EF	49.93	13	3.841	4
65	Rise in the prices of materials	EF	48.75	13	3.75	5
31	Delay in sub-contractor work	C/PM	48.28	13	3.714	6
67	Poor site conditions (location, ground, etc.)	EF	48.16	13	3.705	7
63	Original contract duration is too short	EP	47.99	13	3.692	8
34	Poor site management and supervision by contractor	C/PM	43.74	13	3.365	9
30	Poor communication between contractor with other parties	C/PM	42.99	13	3.307	10
70	External work due to public agencies (roads, and public services)	EF	38.12	13	2.932	11
35	Rework due to errors activities during construction	C/PM	37.42	13	2.878	12
61	Ambiguities, mistakes, and inconsistencies of drawing	EP	35.69	13	2.745	13
23	Ineffective planning and scheduling of the project by contractor	C/PM	33.72	13	2.594	14
20	Loose safety rules and regulations within the contractor’s organization	C/PM	32.94	13	2.534	15
18	Delays in mobilization	C/PM	31.51	13	2.424	16
26	Inefficient quality control by the contractor	C/PM	31.39	13	2.415	17
24	Delays to field survey by the contractor	C/PM	31.30	13	2.408	18
27	Delay in the preparation of contractor submission	C/PM	31.17	13	2.398	19
13	Shortage of technical professionals contractor’s organization	C/PM	29.24	13	2.249	20
25	Ineffective control of project progress by the contractor	C/PM	28.69	13	2.207	21
10	Low skill of manpower	C/MP	28.54	13	2.195	22
1	Shortage of required materials	C/MT	28.35	13	2.181	23
19	Poor controlling of subcontractors by contractor	C/PM	28.07	13	2.159	24
15	Contractor 's poor coordination with other	C/PM	26.76	13	2.068	25
29	Difficulties in financing the project by the contractor	C/PM	24.71	13	1.901	26
7	Shortage of supporting and shoring installations for excavations	C/EQ	24.66	13	1.897	27
68	Poor economic conditions (currency, inflation rate, act)	EF	24.18	13	1.860	28
5	Shortage of required equipment	C/EQ	24.12	13	1.855	29
2	Delay in materials delivery	C/MT	20.96	13	1.612	30
16	Slow preparations of change orders required	C/PM	19.78	13	1.522	31
9	Shortage of manpower (skilled and unskilled labour)	C/MP	18.11	13	1.47	32
4	Changes in materials specifications	C/MT	18.19	13	1.399	33
17	Ineffective contractor head office involvement in the project	C/PM	18.12	13	1.394	34
12	Shortage of contractor’s administrative personnel	C/PM	15.41	13	1.185	35
21	Poor qualifications of the contractor’s assigned to the project	C/PM	11.83	13	0.91	36
69	Waiting time for approval of drawings and test materials	EF	11.65	13	0.896	37
62	Materially differing from contract document	EP	9.39	13	0.722	38
11	Lack of motivation contractor's members	C/MP	9.32	13	0.717	39
6	Failure of equipment	C/EQ	3.65	13	0.281	40
66	Lack of equipment and tools on the market	EF	2.25	13	0.173	41
72	Unexpected Geological Condition	EF	2.23	13	0.172	42
8	Inadequate equipment used for the works	C/EQ	2.20	13	0.196	43
22	Improper technical studies by contractor during bidding stage	C/PM	2.18	13	0.168	44
33	Poor qualification of the contractor’s technical staff	C/PM	2.14	13	0.165	45

e) Ranking of delay factors identified in UK construction projects from owners aspects						
No	**List of Delays Factors**	**Ctg**	**IW**	**R**	**II**	**Rank**
3	Changes in materials prices	MT	70.65	12	5.888	1
42	Financial problems (delayed payments, and economic problems)	OWN	65.41	12	5.451	2
68	Poor economic conditions (currency, inflation rate, etc.)	EF	50.69	12	4.224	3
64	Severe weather conditions on the job site	EF	50.6	12	4.217	4
60	Changes in the scope of the project	EP	50.43	12	4.203	5
41	Contract modifications (replacement and addition of new work)	OWN	44.41	12	3.718	6
47	Slow decision making by the owner organisation	OWN	35.12	12	2.927	7
45	Delay in the settlement of contractor claims by the owner	OWN	32.76	12	2.73	8
39	Slowness in making decisions	OWN	32.33	12	2.694	9
65	Rise in the prices of materials	EF	31.24	12	2.603	10
48	Interference by the owner in the construction operations	OWN	28.81	12	2.401	11
4	Changes in materials specifications	MT	27.47	12	2.927	12
49	Delay in progress payments by the owner	OWN	27.46	12	2.288	13
40	Lack of coordination with contractors	OWN	26.47	12	2,206	14
46	Delay in issuing of change orders by the owner	OWN	25.95	12	2.163	15
61	Ambiguities, mistakes, and inconsistencies of drawings	EP	25.38	12	2.401	16
36	Lack of experience of owner in construction	OWN	24.34	12	2.028	17
10	Low skill of manpower	MP	22.95	12	1.913	18
9	Shortage of manpower (skilled, semi-skilled, unskilled labour)	MP	20.22	12	1.685	19
38	Lack of working knowledge	OWN	19.96	12	1.663	20
43	Delay in delivering the site to the contractor by the owner	OWN	18.96	12	1.580	21
8	Inadequate equipment used for the works	EQ	16.05	12	1.338	22
7	Shortage of supporting and shoring installations for excavations	EQ	15.13	12	1.261	23
1	Shortage of required materials	MT	15.09	12	1.258	24
37	Improper project feasibility study	OWN	14.23	12	1.186	25
5	Shortage of required equipment	EQ	13.36	12	1.113	26
69	Waiting time for approval of drawings and test of materials	EF	13.19	12	1.099	27
66	Lack of equipment and tools on the market	EF	13.17	12	1.095	28
44	Unrealistic contract duration	OWN	11.63	12	0.969	29
2	Delay in materials delivery	MT	10.84	12	0.903	30
70	External work due to public agencies (roads. and public services)	EF	10.76	12	0.897	31
72	Unexpected geological condition	EF	10.32	12	0.86	32
67	Poor site conditions (location, ground, etc.)	EF	9.87	12	0.823	33
75	Rework due to errors during construction	EF	8.64	12	0.720	34
6	Failure of equipment	EQ	6.88	12	0.573	35

f) Ranking of delay factors identified in UK construction projects from consultants aspects						
No	**List of Delays Factors**	**Ctg**	**IW**	**R**	**II**	**Rank**
64	Severe weather conditions on the job site	EF	49.27	19	2.593	1
3	Changes in materials prices	MT	49.14	19	2.586	2
60	Changes in the scope of the project	EP	47.35	19	2.492	3
68	Poor economic conditions (currency, inflation rate, etc.)	EF	31.56	19	1.661	4
59	Poor communication between the consultant and other parties	CNS	30.81	19	1.622	5
63	Original contract duration is too short	EP	26.27	19	1.383	6
51	Delay in the preparation of drawings	CNS	25.39	19	1.336	7
67	Poor site conditions (location, ground, etc.)	EF	23.36	19	1.229	8
65	Rise in the prices of materials	EF	23.29	19	1.226	9
54	Slow response and poor inspection	CNS	22.63	19	1.191	10
1	Shortage of required materials	MT	22.61	19	1.190	11
58	Slowness in giving instruction	CNS	21.81	19	1.148	12
62	Subsurface site conditions materially differing from contract	EP	20.62	19	1.085	13
6	Failure of equipment	EQ	20.55	19	1.082	14
75	Rework due to errors during construction	EF	20.52	19	1.08	15
2	Delay in materials delivery	MT	19.98	19	1.052	16
50	Poor qualification of consultant engineer’s staff	CNS	19.93	19	1.049	17
52	Delay in the approval of consultant submissions by the consultant	CNS	16.82	19	0.885	18
53	Poor design and delays in design	CNS	16.71	19	0.879	19
61	Ambiguities, mistakes, and inconsistencies of drawings	EP	15.02	19	0.791	20
7	Shortage of supporting and shoring installations for excavations	EQ	14.39	19	0.757	21
57	Incomplete design documents	CNS	14.32	19	0.754	22
10	Low skill of manpower	MP	13.28	19	0.699	23
56	Delayed and slow supervision in making decisions	CNS	13.25	19	0.697	24
5	Shortage of required equipment	EQ	12.72	19	0.669	25
55	Absence of consultant’s site staff	CNS	11.62	19	0.612	26
9	Shortage of manpower (skilled, semi-skilled, unskilled labour)	MP	11.06	19	0.582	27
70	External work due to public agencies (roads, and public services	EF	9.54	19	0.502	28
69	Waiting time for approval of drawings and test of materials	EF	7.61	19	0.401	29
66	Lack of equipment and tools on the market	EF	7.11	19	0.374	30
4	Changes in materials specifications	MT	7.09	19	0.373	31
72	Unexpected geological condition	EF	6.97	19	0.367	32
73	Slow site clearance	EF	6.84	19	0.360	33

Appendice-B2:

Statistical analysis of survey data and results discussion

This appendix mainly focuses on analysing the survey data collected from both Libya and the UK construction industry and discussing the results obtained from statistical analysis. The SPSS program was used to test the survey data. Different types of statistical tests are available to test and analyse the delay factors, such as T-Test (one sample t-test, pair sample t-test) and Wilkinson rank test were selected to identify the relationship and confidence level of survey data

1. Paired Samples Test between Libya and UK consultants

The Paired Samples t-test shows a significant relation that exists between two groups from Libyan and UK consultants. The t-value, df and two-tail significance can determine whether the groups come from the same or different population group. However, significance value can also be determined by looking at the probability level (p) specified under the heading two-tail significance. If the probability value is less than the specified alpha value, then the observed t-value is significant. The 95 per cent confidence interval indicates that 95% of the time the interval specified contains the true difference between the population means (Howell, 2007)

Table: 1. Paired Samples T-Test between Libya and UK consultants

Paired Samples Test

		Paired Differences							
					95% Confidence				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	LibConsF - UKconsF	8.04167E0	6.54957	1.19578E0	5.59602E0	1.04873E1	6.725	29	.000
Pair 2	LibConsS - UKconsS	6.36667E0	3.19869	.58400	5.17226E0	7.56108E0	10.902	29	.000

The output of the paired sample t-test presented in table (1) indicates that a significant difference exists between consultants of Libya and UK in terms of frequency and severity scale. The view of the respondent from UK and Libya consultants confirms the significance regarding the causes of delays since value of t (29) = 6.725 and p < .05 in the frequency scale. Similarly, the causes of the delay confirmed by the respondent have significance in the severity scale since value of t (29) = 10.651 and p < .05.

2. One-Sample Test between Libya and UK consultants

This test is conducted to compare the set of scores in the sample to a normally distributed set of scores with the same mean and standard deviation. If the test is non-significant (p> 0.05), then it confirms that the distribution of the sample is not significantly different from a normal distribution (it is probably normal). If, however, the test is significant (p< 0.05) then distribution in question is significantly different from a normal distribution (Nelson, 2004).

Table: 2. One-Sample Test between Libya and UK consultants

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	T	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
LibConsF	15.691	30	.000	17.82258	15.5029	20.1422
UKconsF	26.407	29	.000	9.51667	8.7796	10.2537
LibConsS	36.386	30	.000	15.78226	14.8964	16.6681
UKconsS	26.671	29	.000	9.42500	8.7023	10.1477

The outputs of one sample t-test are presented in table (2) which indicate that the delay factors agreed by Libyan consultants and UK consultants have significant relation in terms of frequency and severity scale. The view of the respondents from Libya consultants confirm the significance regarding the delay factors since value of t (30) = 15.691 and p < .05 in the frequency scale and value of t (30) = 36.38 and p < .05 in the severity scale. Similarly, the delay factors confirmed by the UK respondents have significance in the frequency and severity scale because value of t (29) = 26.41 and p < .05 for frequency and value of t (29) = 26.67 and p < .05 for severity scale.

3. Paired Samples Test between Libya and UK Owners

Table: 3 Paired Samples Test between Libya and UK Owners

Paired Samples Test

	Paired Differences							
				95% Confidence				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pai LibOwnF - UKOwnF	1.58534E1	4.39435	.81601	1.41819E1	17.52497	19.428	28	.000
Pai LibOwmS - UKOwnS	1.61034E1	4.02477	.74738	1.45725E1	17.63439	21.547	28	.000

The output of the paired sample t-test presented in table (3) indicates that a significant difference exists between Owners of Libya and UK in terms of frequency and severity scale. The view of the respondent from UK and Libya Owners confirms the significance regarding the causes of delays since value of $t(28) = 19.43$ and $p < .05$ in the frequency scale. Similarly, the causes of the delay confirmed by the respondent have significance in the severity scale since value of $t(28) = 21.55$ and $p < .05$.

4. One-Sample Test between Libya and UK Owners

Table: 4: One-Sample Test between Libya and UK

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
LibOwnF	28.589	30	.000	21.13710	19.6272	22.6470
UKOwnF	22.209	28	.000	5.20690	4.7266	5.6871
LibOwmS	33.048	30	.000	21.12097	19.8157	22.4262
UKOwnS	28.178	28	.000	4.96552	4.6045	5.3265

The outputs of one sample t-test presented in table (4) indicates that the causes of delay responded by Libyan Owners and UK owners have significance in terms of frequency and severity scale separately. The view of the respondents from Libyan Owner confirms the significance regarding the causes of delays since value of t (30)

= 28.59 and p < .05 in the frequency scale and value of t (30) = 33.05 and p < .05 in the severity scale. Similarly, the causes of the delay confirmed by the UK respondents have significance in the frequency and severity scale because value of t (28) = 22.21 and p < .05 for frequency and value of t (28) = 28.18 and p < .05 for severity scale.

5. Paired Samples Test between Libya and UK Contractors

Table 5 Paired Samples Test between Libya and UK Contractors

Paired Samples Test

	Paired Differences							
				95% Confidence				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1 LibConF - UKConF	7.48837E0	3.83008	.58408	6.30965E0	8.66710	12.82	42	.000
Pair 2 LibConS - UKConS	9.00581E0	3.37907	.51530	7.96589E0	1.00457E	17.47	42	.000

The output of the paired sample t-test presented in table (5) indicates that a significant difference exists between Contractors of Libya and UK in terms of frequency and severity scale. The view of the respondent from UK and Libyan contractors confirms the significance regarding the causes of delays since value of t (42) = 12.82 and p < .05 in the frequency scale. Similarly, the causes of the delay confirmed by the respondent have significance in the severity scale since value of t (42) = 17.48 and p < .05.

6. One-Sample Test between Libya and UK Contractors

Table 6 One-Sample Test between Libya and UK Contractors

One-Sample Test

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
LibConF	32.751	42	.000	15.08140	14.1521	16.0107
UKConF	18.409	42	.000	7.59302	6.7606	8.4254
LibConS	37.482	42	.000	14.76163	13.9668	15.5564
UKConS	16.337	42	.000	5.75581	5.0448	6.4668

The outputs of one sample t-test presented in table (6) indicates that the causes of delay responded by Libyan contractors and UK contractors have significance in terms of frequency and severity scale separately. The view of the respondents from Libyan contractor confirms the significance regarding the causes of delays since value of $t(42) = 32.75$ and $p < .05$ in the frequency scale and value of $t(42) = 37.48$ and $p < .05$ in the severity scale. Similarly, the causes of the delay confirmed by the UK respondents have significance in the frequency and severity scale because value of $t(42) = 18.41$ and $p < .05$ for frequency and value of $t(42) = 16.34$ and $p < .05$ for severity scale.

7. Wilcoxon rank test

7.1 WILCOXON – rank test (Libya and UK Consultants)

The Wilcoxon test is performed in a situation where two sets of scores need to compare, however these two sets of score should come from the same subjects (Nelson, 2004). In this test, consultant is considered as the subject for the scores of impact of delay factors in construction project that are coming from Libyan and UK cases.

After analysis the ranking scores of consultant views between Libya and UK consultants using SPSS, the results of ranked scores are presented in table (7)**.** The first table provides information about the ranked scores. The negative ranks number 26 indicates that UK consultant score is less (negative) than Libyan consultant score whereas positive ranks number 4 indicates that UK consultant scores is more (positive) than Libyan consultant scores in case of frequencies. Similarly, in case of severity score, the negative ranks number 28 indicates that UK consultant score is less (negative) than Libyan consultant score whereas positive ranks number 2 indicates that UK consultant scores is more (positive) than Libyan consultant scores. However, there are no numbers that ties (same) scores between UK and Libyan consultant scores. For more details, follow the footnotes of the table, which show the relationship between positive and negative ranks of UK and Libyan Consultants scores.

The advantage of this approach is that it allows exact significance values to be calculated based on the normal distribution.

The second table in SPSS output (8) shows that the test statistic is based on the negative ranks, that the z-score is -4.704 for frequency and -4.586 for severity. This value is significant since the value of $p = 0.00$. Therefore, the value is based on the negative ranks and concluded that Libya and UK consultants was a significant ($z = -4.704, -4.586$, $p < 0.01$) for frequency and severity cases. Additionally, result is presented by a normal distribution graph as shown in Figures (1 and 2) that the pattern of results found with the Wilcoxon test are significant for both frequency and severity cases in Libyan and UK consultant scores.

Table 7 WILCOXON – RANK TEST between Libya and UK consultants

Ranks Test

		N	Mean Rank	Sum of Ranks
UKconsF - LibConsF	Negative Ranks	26[a]	16.96	441.00
	Positive Ranks	4[b]	6.00	24.00
	Ties	0[c]		
	Total	30		
UKconsS - LibConsS	Negative Ranks	28[d]	16.50	462.00
	Positive Ranks	2[e]	1.50	3.00
	Ties	0[f]		
	Total	30		

a. UKconsF < LibConsF

b. UKconsF > LibConsF

c. UKconsF = LibConsF

d. UKconsS < LibConsS

e. UKconsS > LibConsS

Table 8: Test Statistics[b]

	UKconsF - LibConsF	UKconsS - LibConsS
Z	-4.289[a]	-4.722[a]
Asymp. Sig. (2-	.000	.000

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

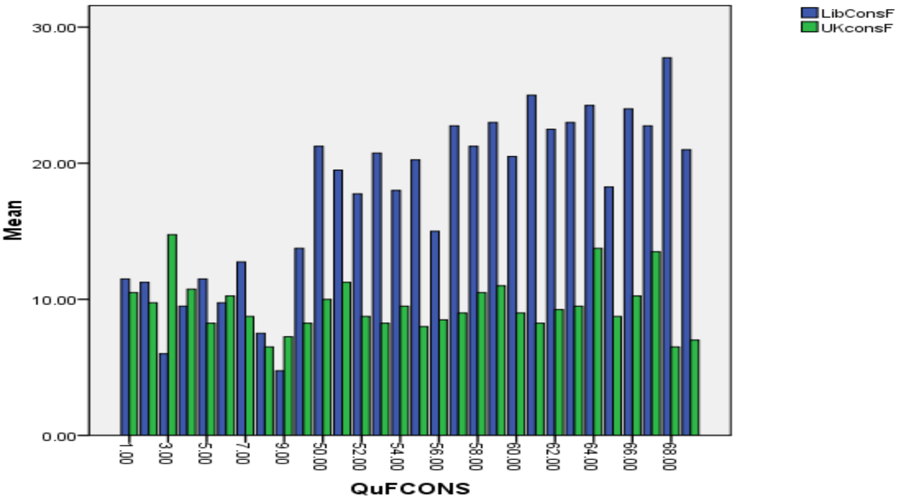


Figure 1: delay factors in frequency scale of UK and Libyan consultant

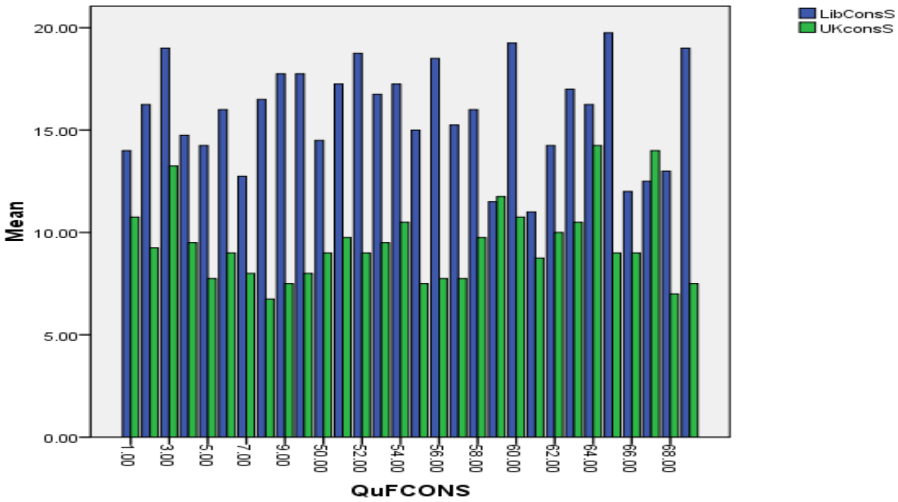


Figure 2: delay factors in severity scale of UK and Libyan consultant

7. 2 WILCOXON – rank test (Libya and UK Owners)

After analysis the ranking scores of owner views between Libya and UK owners using SPSS 16, the results of ranked scores are presented in table (9). The first table provides information about the ranked scores. The negative ranks number 29 indicates that UK owner score is less (negative) than Libyan owner score whereas positive ranks number 0 indicates that UK owner scores is more (positive) than Libyan owner scores in case of frequencies. Similarly, in case of severity score, the negative ranks number 29 indicates that Libyan owner score is less (negative) than

UK owner score whereas positive ranks number 2 indicates that Libyan owner scores is more (positive) than UK owner scores. For more details, follow the footnotes of the table, which show the relationship between positive and negative ranks of UK and Libyan owners' scores.

The second table in SPSS output (10) shows that the test statistic is based on the negative ranks, that the z - score is -4.704 for frequency and - 4.586 for severity. This value is significant since the value of p = 0.00. Therefore, the value is based on the negative ranks and concluded that Libya and UK owners was a significant (z = -4.704, -4586, p < 0.00) for both frequency and severity scale. Additionally, result is presented by a normal distribution graph as shown in figures (3 and 4) that the pattern of results found with Wilcoxon test are significant for both frequency and severity cases in Libyan and UK owner scores.

Table 9: WILCOXON – RANK TEST between Libya and UK Owners

Ranks Test

		N	Mean Rank	Sum of Ranks
UKOwnF - LibOwnF	Negative Ranks	29[a]	15.00	435.00
	Positive Ranks	0[b]	.00	.00
	Ties	0[c]		
	Total	29		
LibOwnS - LibOwmS	Negative Ranks	29[d]	16.62	482.00
	Positive Ranks	2[e]	7.00	14.00
	Ties	0[f]		
	Total	31		

a. UKOwnF < LibOwnF

b. UKOwnF > LibOwnF

c. UKOwnF = LibOwnF

d. LibConS < LibOwmS

e. LibConS > LibOwmS

f. LibConS = LibOwmS

Table 10: Test Statistics[b]

	UKOwnF - LibOwnF	LibOwnS - LibOwnS
Z	-4.704[a]	-4.586[a]
Asymp. Sig. (2-tailed)	.000	.000

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

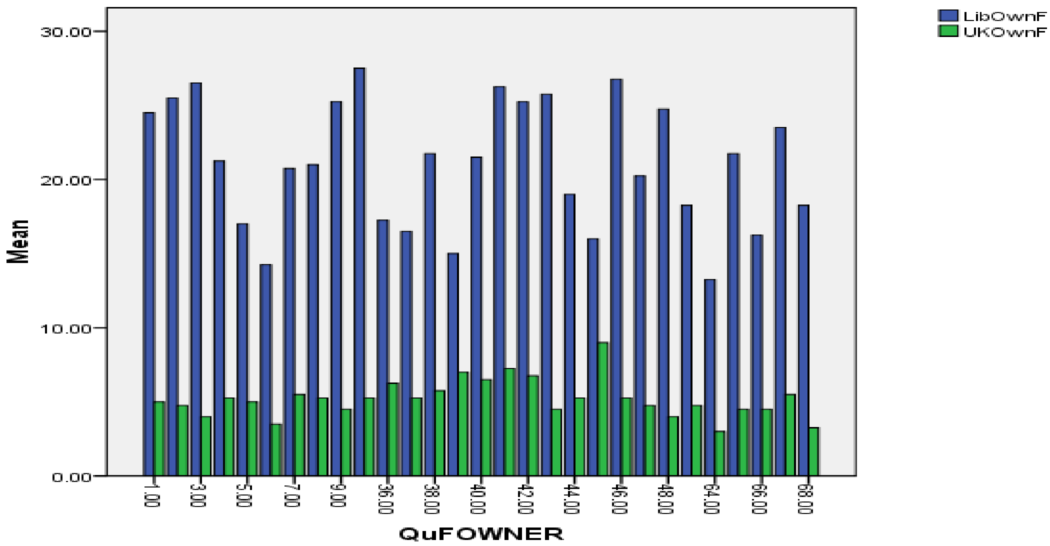


Figure 3: delay factors in frequency scale of UK and Libyan owners

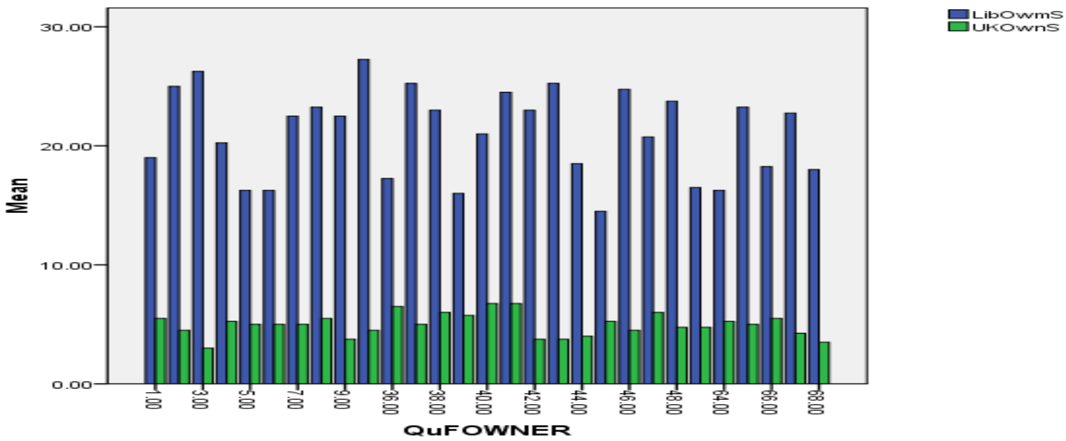


Figure 4: delay factors in severity scale of UK and Libyan owners

3.3 WILCOXON – rank test (Libya and UK Contractors)

After analysis the ranking scores of consultant views between Libya and UK contractors using SPSS, the results of ranked scores are presented in table (11**).** The first table provides information about the ranked scores. The negative ranks number 42 indicates that UK contractor score is less (negative) than Libyan contractors score whereas positive ranks number 1 indicates that UK contractor scores is more (positive) than Libyan contractors scores in case of frequencies. Similarly, in case of severity score, the negative ranks number 43 indicates that UK contractor score is less (negative) than Libyan contractor score whereas positive ranks number 0 indicates that UK contractor scores is more (positive) than Libyan contractor scores. For more details, follow the footnotes of the table, which show the relationship between positive and negative ranks of UK and Libyan Contractors scores.

The second table in SPSS output (12) shows that the test statistic is based on the negative ranks, that the z - score is -5.689 for frequency and -5.713 for severity. This value is significant since the value of $p = 0.00$. Therefore, the value is based on the negative ranks and concluded that Libya and UK contractors was a significant ($z = -5.689, -5.713, p < 0.00$) for frequency and severity cases.

Additionally, result is presented in a normal distribution graph as shown in figures (5 and 6). The results found with the Wilcoxon test showed there are significant for both frequency and severity scale of Libyan and UK contractor scores.

Table: 11: WILCOXON SIGNED – RANK TEST between Libya and UK Contractors

Ranks Test

		N	Mean Rank	Sum of Ranks
UKConF - LibConF	Negative Ranks	42[a]	22.48	944.00
	Positive Ranks	1[b]	2.00	2.00
	Ties	0[c]		
	Total	43		
UKConS - LibConS	Negative Ranks	43[d]	22.00	946.00
	Positive Ranks	0[e]	.00	.00
	Ties	0[f]		
	Total	43		

a. UKConF < LibConF

b. UKConF > LibConF

c. UKConF = LibConF

d. UKConS < LibConS

e. UKConS > LibConS

f. UKConS = LibConS

Table: 12: Test Statistics

	UKConF - LibConF	UKConS - LibConS
Z	-5.689[a]	-5.713[a]
Asymp. Sig. (2-tailed)	.000	.000

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

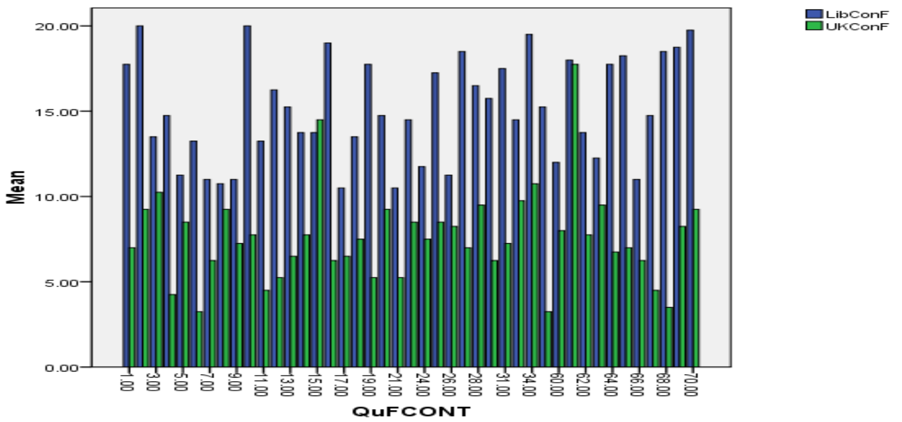


Figure 5: delay factors in frequency scale of UK and Libyan contractors

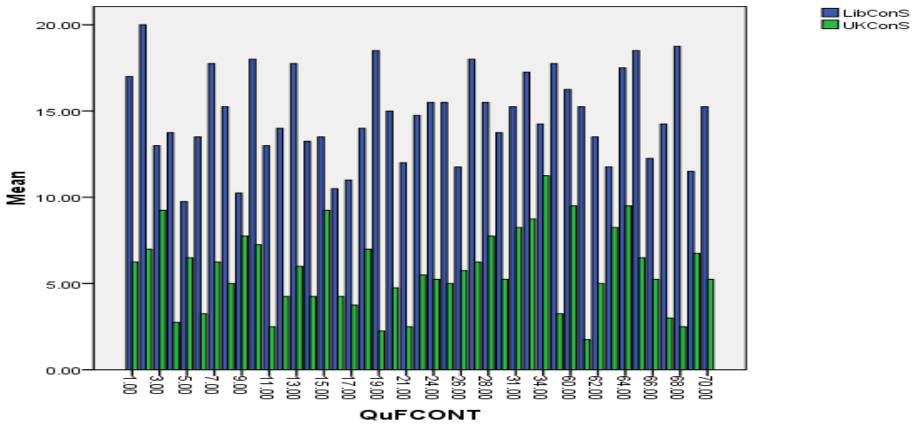


Figure 6: delay factors in severity scale of UK and Libyan contractors

The statistical tests conclude that the survey data are significant. The significance value of the survey data indicate that there is a probability of delay in the construction project due to several delay factors, which were identified through industry survey. The relative importance of each of the frequency and severity scale of delay factors perceived by the respondents were tested at 95% of confidence level. The P-values for both scale of frequency and severity for all three groups such as owners, consultants and contractors were found less than 0.05 in both countries Libya and UK. Therefore, it is concluded that the survey results are significant. The results exposed that assumptions made in this study related to the delay factors in construction project and tested by different statistical tests are significant and correct.

Appendices-C 1) The critical work activities identified by Ms Project (**case study 1**). In the both case studies, MS project used to identify the critical activities of the building project so that delay in each critical activity can analyse and identified possible delay due to the delay factors. Duration and slack time of each activity of the project are shown below.

ID	ID	Task Name	Duration	Start	Finish	Predecessors	Total Slack
1	1	**1 Block 1 (BAB TARABLUS)**	**373 days**	**Sun 17/05/09**	**Mon 24/05/10**		**0 days**
2	2	**1.1 Structural works**	**231 days**	**Sun 17/05/09**	**Sat 02/01/10**		**9 days**
3	3	**1.1.1 General works**	**43 days**	**Sun 17/05/09**	**Sun 28/06/09**		**9 days**
4	4	1.1.1.1 Excavation	4 days	Sun 17/05/09	Wed 20/05/09		9 days
5	5	1.1.1.2 Lean concrete	1 day	Mon 25/05/09	Mon 25/05/09	4FS+4 days	9 days
6	6	1.1.1.3 Founda formwork erection	2 days	Tue 16/06/09	Wed 17/06/09	5FS+21 days	9 days
7	7	1.1.1.4 Foundation rebar fixing	5 days	Thu 18/06/09	Mon 22/06/09	6	9 days
8	8	1.1.1.5 Foundation concrete pouring	1 day	Tue 23/06/09	Tue 23/06/09	7	9 days
9	9	1.1.1.6 Isolation works	4 days	Wed 24/06/09	Sat 27/06/09	8	9 days
10	10	1.1.1.7 Back filling	1 day	Sun 28/06/09	Sun 28/06/09	9	9 days
11	**11**	**1.1.2 Ground Floor (GF)**	**11 days**	**Sat 03/10/09**	**Tue 13/10/09**		**0 days**
12	12	1.1.2.1 Ground floor wall & column rebar	2 days	Sat 03/10/09	Sun 04/10/09	10FS+90 days	3 days
13	13	1.1.2.2 Ground floor wall & column	4 days	Sun 04/10/09	Wed 07/10/09	12SS-1 day	0 days
14	14	1.1.2.3 Ground floor wall & column concrete	4 days	Sun 04/10/09	Wed 07/10/09	13SS	0 days
15	15	1.1.2.4 Ground floor slab formwork Slab Formwo	5 days	Tue 06/10/09	Sat 10/10/09	14FS-2 days	0 days
16	16	1.1.2.5 Ground floor slab rebar fixing	5 days	Thu 08/10/09	Mon 12/10/09	15FS-3 days	0 days
17	17	1.1.2.6 Ground floor slab concrete	1 day	Tue 13/10/09	Tue 13/10/09	16	0 days
18	**18**	**1.1.3 Floor 1**	**11 days**	**Wed 14/10/09**	**Sat 24/10/09**		**0 days**
19	19	1.1.3.1 Floor wall & columan rebar	2 days	Wed 14/10/09	Thu 15/10/09	17	0 days
20	20	1.1.3.2 Floor wall & columan	4 days	Wed 14/10/09	Sat 17/10/09	19SS	0 days
21	21	1.1.3.3 Floor wall & columan concrete	4 days	Wed 14/10/09	Sat 17/10/09	20FS-4 days	0 days
22	22	1.1.3.4 Floor slab formwork	5 days	Fri 16/10/09	Tue 20/10/09	21FS-2 days	0 days
23	23	1.1.3.5 Floor slab rebar fixing	5 days	Mon 19/10/09	Fri 23/10/09	22FS-2 days	0 days
24	24	1.1.3.6 Floor slab concrete pouring	1 day	Sat 24/10/09	Sat 24/10/09	23	0 days
25	**25**	**1.1.4 Floor 2**	**11 days**	**Sun 25/10/09**	**Wed 04/11/09**		**0 days**
26	26	1.1.4.1 Floor wall & columan rebar	2 days	Sun 25/10/09	Mon 26/10/09	24	0 days
27	27	1.1.4.2 Floor wall & columan	4 days	Sun 25/10/09	Wed 28/10/09	26SS	0 days
28	28	1.1.4.3 Floor wall & columan concrete	4 days	Sun 25/10/09	Wed 28/10/09	27FS-4 days	0 days
29	29	1.1.4.4 Floor slab formwork	5 days	Tue 27/10/09	Sat 31/10/09	28FS-2 days	0 days
30	30	1.1.4.5 Floor slab rebar fixing	5 days	Fri 30/10/09	Tue 03/11/09	29FS-2 days	0 days
31	31	1.1.4.6 Floor slab concrete pouring	1 day	Wed 04/11/09	Wed 04/11/09	30	0 days
32	**32**	**1.1.5 Floor 3**	**11 days**	**Thu 05/11/09**	**Sun 15/11/09**		**0 days**
33	33	1.1.5.1 Floor wall & columan rebar	2 days	Thu 05/11/09	Fri 06/11/09	31	0 days
34	34	1.1.5.2 Floor wall & columan	4 days	Thu 05/11/09	Sun 08/11/09	33SS	0 days
35	35	1.1.5.3 Floor wall & columan concrete	4 days	Thu 05/11/09	Sun 08/11/09	34FS-4 days	0 days
36	36	1.1.5.4 Floor slab formwork	5 days	Sat 07/11/09	Wed 11/11/09	35FS-2 days	0 days
37	37	1.1.5.5 Floor slab rebar fixing	5 days	Tue 10/11/09	Sat 14/11/09	36FS-2 days	0 days
38	38	1.1.5.6 Floor slab concrete pouring	1 day	Sun 15/11/09	Sun 15/11/09	37	0 days
39	**39**	**1.1.6 Floor 4**	**11 days**	**Mon 16/11/09**	**Thu 26/11/09**		**0 days**
40	40	1.1.6.1 Floor wall & columan rebar	2 days	Mon 16/11/09	Tue 17/11/09	38	0 days
41	41	1.1.6.2 Floor wall & columan	4 days	Mon 16/11/09	Thu 19/11/09	40SS	0 days

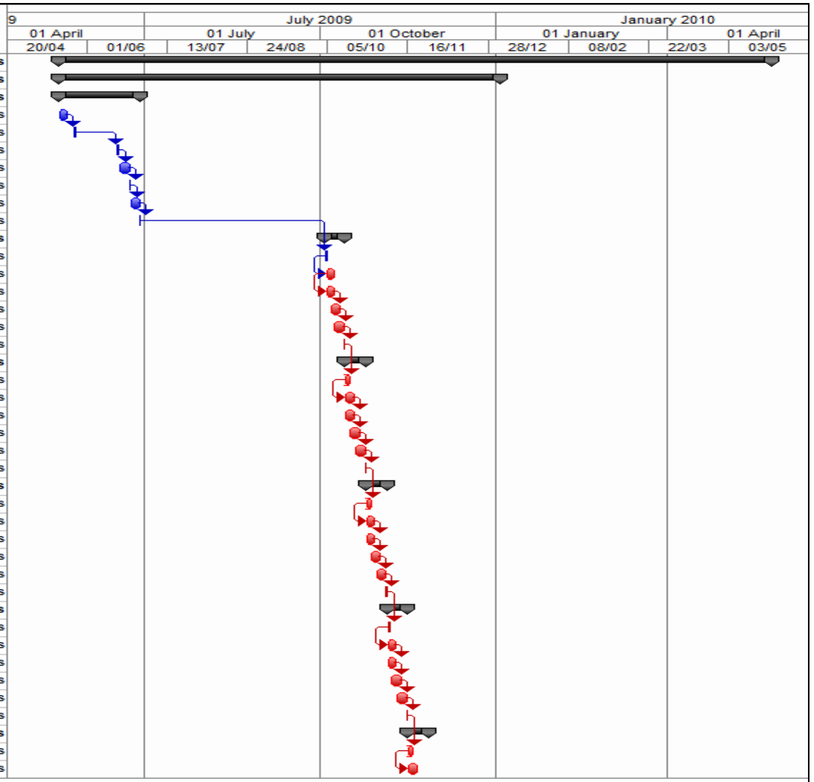


Figure show project planning

Appendices-C 2) the critical work activities identified by Ms Project (**case study 2**)

ID	ID	WBS	Task Name	Duration	Start	Finish	Predecessors	Total Slack
1	**1**	**1**	**Project of Educational and Office Building**	**332 days**	**Mon 23/08/04**	**Tue 29/11/05**		**0 days**
2	2	1.1	site preparation for work	2 days	Mon 23/08/04	Tue 24/08/04		0 days
3	**3**	**1.2**	**foundations works:**	**66 days**	**Wed 25/08/04**	**Wed 24/11/04**		**0 days**
4	4	1.2.1	Drilling	4 days	Wed 25/08/04	Mon 30/08/04	2	0 days
5	5	1.2.2	Concrete under foundations	5 days	Sun 29/08/04	Thu 02/09/04	4FS-2 days	0 days
6	6	1.2.3	work and supply foundation concrete	15 days	Sun 05/09/04	Thu 23/09/04	5	0 days
7	7	1.2.4	column under ground beams	13 days	Sun 26/09/04	Tue 12/10/04	6	0 days
8	8	1.2.5	concrete-brick under ground beams	9 days	Wed 13/10/04	Mon 25/10/04	7	0 days
9	9	1.2.6	ground beams	13 days	Tue 26/10/04	Thu 11/11/04	8	0 days
10	10	1.2.7	Backfilling of foundation	9 days	Sun 14/11/04	Wed 24/11/04	9	0 days
11	**11**	**1.3**	**ground floor works**	**81 days**	**Thu 25/11/04**	**Thu 17/03/05**		**0 days**
12	12	1.3.1	column	15 days	Thu 25/11/04	Wed 15/12/04	10	0 days
13	13	1.3.2	Slab	33 days	Thu 16/12/04	Mon 31/01/05	12	0 days
14	14	1.3.3	concrete-brick	11 days	Tue 01/02/05	Tue 15/02/05	13	183 days
15	15	1.3.4	thresholds	5 days	Wed 16/02/05	Tue 22/02/05	14	183 days
16	16	1.3.5	Electric works	2 days	Wed 23/02/05	Thu 24/02/05	15	183 days
17	17	1.3.6	water and sewage work	13 days	Wed 23/02/05	Sun 13/03/05	16SS	183 days
18	18	1.3.7	Installation of doors's frames	2 days	Thu 24/02/05	Sun 27/02/05	17SS+1 day	183 days
19	19	1.3.8	work of the internal cement state	14 days	Mon 28/02/05	Thu 17/03/05	18	183 days
20	**20**	**1.4**	**First floor works**	**70 days**	**Tue 01/02/05**	**Mon 09/05/05**		**0 days**
21	21	1.4.1	columns	14 days	Tue 01/02/05	Sun 20/02/05	13	0 days
22	22	1.4.2	Slab	30 days	Mon 21/02/05	Sun 03/04/05	21	0 days
23	23	1.4.3	Concrete-brick	3 days	Mon 04/04/05	Wed 06/04/05	22	146 days
24	24	1.4.4	Thresholds	6 days	Thu 07/04/05	Thu 14/04/05	23	146 days
25	25	1.4.5	Electric works	2 days	Sun 17/04/05	Mon 18/04/05	24	146 days
26	26	1.4.6	water and sewage works	13 days	Sun 17/04/05	Tue 03/05/05	25SS	146 days
27	27	1.4.7	Installation of doors's frames	2 days	Mon 18/04/05	Tue 19/04/05	26SS+1 day	146 days
28	28	1.4.8	work of the internal cement state	14 days	Wed 20/04/05	Mon 09/05/05	27	146 days
29	**29**	**1.5**	**Second floor works**	**70 days**	**Mon 04/04/05**	**Sun 10/07/05**		**0 days**
30	30	1.5.1	columns	14 days	Mon 04/04/05	Thu 21/04/05	22	0 days
31	31	1.5.2	Slab	30 days	Sun 24/04/05	Thu 02/06/05	30	0 days
32	32	1.5.3	concrete-brick	3 days	Sun 05/06/05	Tue 07/06/05	31	102 days
33	33	1.5.4	thresholds	6 days	Wed 08/06/05	Wed 15/06/05	32	102 days
34	34	1.5.5	Electric works	2 days	Thu 16/06/05	Sun 19/06/05	33	102 days
35	35	1.5.6	water and sewage works	13 days	Thu 16/06/05	Mon 04/07/05	34SS	102 days
36	36	1.5.7	Installation of doors's frames	2 days	Thu 16/06/05	Sun 19/06/05	35SS	102 days
37	37	1.5.8	work of the internal cement state	14 days	Tue 21/06/05	Sun 10/07/05	36FS+1 day	102 days
38	**38**	**1.6**	**Third floor works**	**70 days**	**Sun 05/06/05**	**Thu 08/09/05**		**0 days**
39	39	1.6.1	Column	14 days	Sun 05/06/05	Wed 22/06/05	31	0 days
40	40	1.6.2	Slab	30 days	Thu 23/06/05	Wed 03/08/05	39	0 days
41	41	1.6.3	Concrete-brick	3 days	Thu 04/08/05	Mon 08/08/05	40	10 days

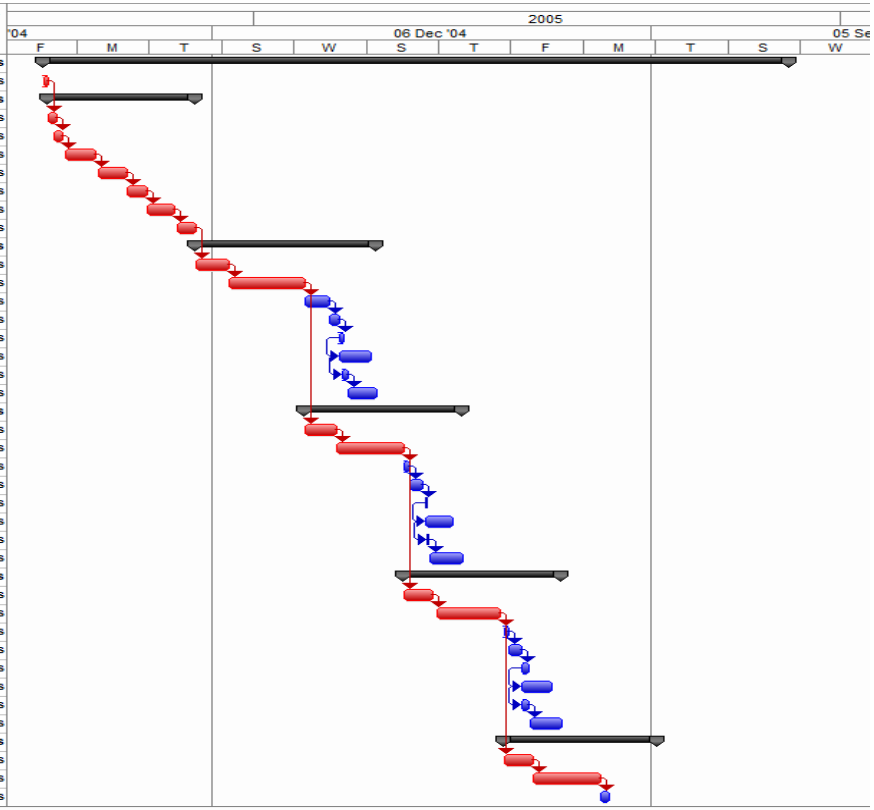


Figure show project planning

Appendices-D 1: Table showing influence values of each delay factor (found from Libya) in case study-1.

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
13,14	69	waiting time for approval of drawings	76.73	0.35
	64	Severe weather conditions on the job site	65.27	0.30
	2	Delay in materials delivery	75.96	0.35
			217.96	1.00

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
15,16,17	65	Rise in the prices of materials	59.59	0.30
	56	Delayed and slow supervision in making decisions	84.41	0.42
	1	Shortage of required materials	56.60	0.28
			200.6	1.00

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
19,20,21	60	Changes in the scope of the project	62.89	0.31
	46	Delay in issuing of change orders by the owner	84.45	0.41
	1	Shortage of required materials	56.60	0.28
			203.94	1.00

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
22,23,24	65	Rise in the price of material	59.59	0.27
	57	Incomplete design documents	83.2	0.38
	42	Financial problems (delayed payments, financial difficulties, and economic problems)	74.04	0.34
			216.83	1.00

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
26,27,28	57	Incomplete design documents	83.2	0.41
	48	Interference by the owner in the construction operations	74.98	0.37
	4	Changes in materials specification	46.63	0.23
			204.81	1.00

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
29,30,31	56	Delayed and slow supervision in making decisions	84.81	0.41
	5	Shortage of required equipment	45.57	0.22
	2	Delay in material delivery	75.96	0.37
			206.34	1.00

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
33,34,35	65	Rise in the price of material	59.59	0.21
	61	Ambiguities, mistakes, and inconsistencies	60.86	0.22
	51	Delay in the preparation of drawing	72.3	0.26
	45	Delay in the settlement of contractor claims by the owner	88.73	0.32
			281.48	1.00

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
36,37,38	53	Poor design and delays in design	63.85	0.37
	36	Lack of experience of owner in construction	65.36	0.37
	5	Shortage of required equipment	45.47	0.26
			174.68	1.00

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
40,41,42	58	Slowness in giving instruction	63.1	0.28
	55	Absence of consultant's site staff	50.63	0.23
	47	Slow decision making by the owner organisation	53.59	0.24
	40	Lack of coordination with contractors	57.59	0.26
			224.91	1.00

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
43,44,45	65	Rise in the price of material	59.59	0.29
	51	Delay in the preparation of drawing	72.3	0.35
	2	Delay in material delivery	75.96	0.37
			207.85	1.00

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
47,48,49	48	Interference by the owner in the construction operations	74.98	0.36
	42	Financial problems (delayed payments, financial difficulties, and economic problems)	74.04	0.36
	1	Shortage of required materials	56.6	0.28
			205.62	1.00

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
50,51,52	45	Delay in the settlement of contractor claims by the owners hostage of material	88.73	0.28
	5	Shortage of required equipment	45.47	0.14
	3	Changes in materials prices	50.10	0.16
	2	Delay in materials delivery	75.96	0.24
	1	Shortage of required materials	56.6	0.18
			316.86	1.00

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
70	60	Changes in the scope of the project	62.89	0.29
	57	Incomplete design documents	83.2	0.38
	42	Financial problems (delayed payments, financial difficulties, and economic problems)	74.04	0.34
			220.13	1.00

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
122 to 136 (Electrical works for all floors)	46	Delay in issuing of change orders by the owner	84.45	0.35
	41	Contract modifications (replacement and addition of new work)	82.03	0.34
	2	Delay in materials delivery	75.96	0.31
			242.44	1.00

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
139 to 153 (Mechanical works)	65	Rise in the price of material	59.59	0.21
	60	Changes in the scope of the project	62.89	0.22
	57	Incomplete design documents	83.2	0.30
	42	Financial problems (delayed payments, financial difficulties, and economic problems)	74.04	0.26
			279.72	1.00

Appendices- D 2: Table showing influence values of each delay factor (found from the UK) in case study-1.

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
13,14	69	waiting time for approval of drawings	10.82	0.14
	64	Severe weather conditions on the job site	49.93	0.64
	2	Delay in materials delivery	17.26	0.22
			78.01	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
15,16,17	65	Rise in the prices of materials	34.43	0.49
	56	Delayed and slow supervision in making decisions	13.25	0.19
	1	Shortage of required materials	22.02	0.32
			69.7	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
19,20,21	60	Changes in the scope of the project	51.97	0.52
	46	Delay in issuing of change orders by the owner	25.95	0.26
	1	Shortage of required materials	22.02	0.22
			99.94	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
22,23,24	65	Rise in the price of material	34.43	0.30
	57	Incomplete design documents	14.32	0.13
	42	Financial problems (delayed payments, financial difficulties, and economic problems)	65.41	0.57
			114.16	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
26,27,28	57	Incomplete design documents	14.32	0.24
	48	Interference by the owner in the construction operations	28.81	0.47
	4	Changes in materials specification	17.58	0.29
			60.71	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
29,30,31	56	Delayed and slow supervision in making decisions	13.25	0.28
	5	Shortage of required equipment	16.73	0.35
	2	Delay in material delivery	17.26	0.37
			47.24	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
33,34,35	65	Rise in the price of material	34.43	0.29
	61	Ambiguities, mistakes, and inconsistencies	25.36	0.22
	51	Delay in the preparation of drawing	25.39	0.22
	45	Delay in the settlement of contractor claims by the owner	32.76	0.28
			117.94	1.00

Critical activity No	Causes ID NO	The most critical delay factors in Libyan construction industry	IW	Influence factors
36,37,38	53	Poor design and delays in design	16.71	0.29
	36	Lack of experience of owner in construction	24.34	0.42
	5	Shortage of required equipment	16.73	0.29
			57.78	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
40,41,42	58	Slowness in giving instruction	21.81	0.23
	55	Absence of consultant’s site staff	11.62	0.12
	47	Slow decision making by the owner organisation	35.12	0.37
	40	Lack of coordination with contractors	26.47	0.28
			95.02	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
43,44,45	65	Rise in the price of material	34.43	0.45
	51	Delay in the preparation of drawing	25.39	0.33
	2	Delay in material delivery	17.26	0.22
			77.08	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
47,48,49	48	Interference by the owner in the construction operations	28.81	0.25
	42	Financial problems (delayed payments, financial difficulties, and economic problems)	65.41	0.56
	1	Shortage of required materials	22.02	0.19
			116.24	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
50,51,52	45	Delay in the settlement of contractor claims by the owner	32.76	0.22
	5	Shortage of required equipment	16.73	0.11
	3	Changes in materials prices	60.7	0.41
	2	Delay in materials delivery	17.26	0.12
	1	Shortage of required materials	22.02	0.15
			149.43	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
70	60	Changes in the scope of the project	51.97	0.39
	57	Incomplete design documents	14.32	0.11
	42	Financial problems (delayed payments, financial difficulties, and economic problems)	65.41	0.50
			131.7	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
122 to 136 (Electrical works for all floors)	46	Delay in issuing of change orders by the owner	25.95	0.30
	41	Contract modifications (replacement and addition of new work)	44.61	0.51
	2	Delay in materials delivery	17.26	0.197
			87.82	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
139 to 153 (Mechanical works)	65	Rise in the price of material	34.43	0.21
	60	Changes in the scope of the project	51.97	0.31
	57	Incomplete design documents	14.32	0.09
	42	Financial problems (delayed payments, financial difficulties, and economic problems)	65.41	0.39
			166.13	1.00

Appendices-E 1: Table showing influence values of each delay factor (found from Libya) in case study-2.

Critical activity No	Causes ID NO	The critical delay factors in Libyan construction industry	IW	Influence of factors
2	69	waiting time for approval of drawings and test samples of materials	76.73	0.29
	64	Severe weather conditions on the job site	65.27	0.25
	43	Delay in furnishing and delivering the site to the contractor by the owner	82.93	0.31
	8	Inadequate equipment used for the works	41.32	0.16
			266.25	1.00

Critical activity No	Causes ID NO	The critical delay factors in Libyan construction industry	IW	Influence of factors
4,5,6	60	Changes in the scope of the project	62.89	0.36
	10	Low skill of manpower	68.97	0.40
	8	Inadequate equipment used for the works	41.32	0.24
			173.18	1.00

Critical activity No	Causes ID NO	The critical delay factors in Libyan construction industry	IW	Influence of factors
7,8,9,10	65	Rise in the price of material	59.59	0.19
	57	Incomplete design documents	83.2	0.26
	13	Shortage of technical professionals in the contractor's organization	46.99	0.15
	10	Low skill of manpower	68.97	0.22
	1	Shortage of required materials	56.6	0.18
			315.35	1.00

Critical activity No	Causes ID NO	The critical delay factors in Libyan construction industry	IW	Influence of factors
12,13	61	Ambiguities, mistakes, and inconsistencies	60.86	0.22
	53	Poor planning and design	63.85	0.23
	51	Delay in the preparation of drawing	72.3	0.26
	2	Delay in material delivery	75.96	0.28
			272.97	1.00

Critical activity No	Causes ID NO	The critical delay factors in Libyan construction industry	IW	Influence of factors
21, 22,30,31, 39, 40	65	Rise in the price of material	59.59	0.17
	57	Incomplete design documents	83.2	0.24
	42	Financial problems (delayed payments, financial difficulties, and economic problems)	74.04	0.22
	10	Low skill of manpower	68.79	0.20
	1	Shortage of required materials	56.6	0.17
			342.22	1.00

Critical activity No	Causes ID NO	The critical delay factors in Libyan construction industry	IW	Influence of factors
48,49				
	57	Incomplete design documents	83.2	0.30
	10	Low skill of manpower	68.79	0.25
	4	Changes in materials specification	46.63	0.17
	2	Delay in material delivery	75.96	0.28
			274.58	1.00

Critical activity No	Causes ID NO	The critical delay factors in Libyan construction industry	IW	Influence of factors
52,53	65	Rise in the price of material	59.59	0.14
	48	Interference by the owner in the construction operations	74.98	0.18
	57	Incomplete design documents	83.2	0.20
	42	Financial problems (delayed payments, financial difficulties, and economic problems)	74.04	0.18
	10	Low skill of manpower	68.79	0.16
	1	Shortage of required materials	56.6	0.14
			417.2	1.00

Critical activity No	Causes ID NO	The critical delay factors in Libyan construction industry	IW	Influence of factors
54,59	64	Severe weather conditions on the job site	65.27	0.18
	45	Delay in the settlement of contractor claims by the owner	88.78	0.25
	10	Low skill of manpower	68.79	0.19
	2	Delay in materials delivery	75.96	0.21
	1	Shortage of required materials	56.6	0.16
			355.4	1.00

Critical activity No	Causes ID NO	The critical delay factors in Libyan construction industry	IW	Influence of factors
61,62	65	Rise in the price of material	59.59	0.13
	48	Interference by the owner in the construction operations	74.98	0.17
	46	Delay in issuing of change orders by the owner	84.45	0.19
	42	Financial problems (delayed payments, financial difficulties, and economic problems)	74.04	0.16
	41	Contract modifications (replacement and addition of new work)	82.03	0.18
	2	Delay in materials delivery	75.96	0.17
			451.05	1.00

Critical activity No	Causes ID NO	The critical delay factors in Libyan construction industry	IW	Influence of factors
63	56	Delayed and slow supervision in making decisions	84.81	0.32
	50	Poor qualification of consultant engineer's staff assigned to the project	90.25	0.34
	45	Delay in the settlement of contractor claims by the owner	88.73	0.34
			263.79	1.00

Appendix-E2: Table showing influence values of each delay factor (found from UK) in case study-2.

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
2	69	waiting time for approval of drawings	10.82	0.12
	64	Severe weather conditions on the job site	49.93	0.56
	43	Delay in furnishing and delivering the site to the contractor by the owner	18.96	0.21
	8	Inadequate equipment used for the works	9.13	0.10
			88.835	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
4,5,6	60	Changes in the scope of the project	51.97	0.64
	10	Low skill of manpower	20.56	0.25
	8	Inadequate equipment used for the works	9.13	0.11
			81.66	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
7,8,9,10	65	Rise in the price of material	34.43	0.29
	57	Incomplete design documents	14.32	0.12
	13	Shortage of technical professionals in the contractor's organization	29.24	0.24
	10	Low skill of manpower	20.56	0.17
	1	Shortage of required materials	22.02	0.18
			120.57	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
12,13	61	Ambiguities, mistakes, and inconsistencies	25.36	0.30
	53	Poor planning and design	16.71	0.20
	51	Delay in the preparation of drawing	25.39	0.30
	2	Delay in material delivery	17.24	0.20
			84.71	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
21, 22,30,31, 39, 40	65	Rise in the price of material	34.43	0.22
	57	Incomplete design documents	14.32	0.09
	42	Financial problems	65.41	0.42
	10	Low skill of manpower	20.56	0.13
	1	Shortage of required materials	22.02	0.14
			156.74	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
48,49				
	57	Incomplete design documents	14.32	0.21
	10	Low skill of manpower	20.56	0.29
	4	Changes in materials specification	17.58	0.25
	2	Delay in material delivery	17.24	0.25
			69.71	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
52,53	65	Rise in the price of material	34.43	0.19
	48	Interference by the owner in the construction operations	28.81	0.16
	57	Incomplete design documents	14.32	0.08
	42	Financial problems	65.41	0.35
	10	Low skill of manpower	20.56	0.11
	1	Shortage of required materials	22.02	0.12
			185.55	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
54,59	64	Severe weather conditions	49.93	0.35
	45	Delay in the settlement of contractor claims by the owner	32.76	0.23
	10	Low skill of manpower	20.56	0.14
	2	Delay in materials delivery	17.24	0.12
	1	Shortage of required materials	22.02	0.15
			142.52	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
61,62	65	Rise in the price of material	34.43	0.16
	48	Interference by the owner in the construction operations	28.81	0.13
	46	Delay in issuing of change orders by the owner	25.95	0.12
	42	Financial problems	65.41	0.30
	41	Contract modifications (replacement and addition of new work)	44.41	0.21
	2	Delay in materials delivery	17.24	0.08
			216.25	1.00

Critical activity No	Causes ID NO	The most critical delay factors in UK construction industry	IW	Influence factors
63	56	Delayed and slow supervision in making decisions	13.25	0.20
	50	Poor qualification of consultant engineer's staff assigned to the project	19.93	0.30
	45	Delay in the settlement of contractor claims by the owner	32.76	0.50
			65.94	1.00

Appendix-F1: Table showing duration of each critical activity of case study-1

Activity No	Random 1	Random 2	Random 3	Random 4	Random 5	Rand 1 RF 1	Rand 2 RF 2	Rand 3 RF 3	Ran 4 RF 4	Rand 5 RF 5	Duration of activity
	C ID 2	**C ID 64**	**C ID 69**			**C ID 2**	**C ID 64**	**C ID 69**			
13	0.60	0.63	0.62			0.35	0.3	0.35			**4.09**
14	0.66	0.60	0.63			0.35	0.3	0.35			**4.11**
	C ID 1	**C ID 56**	**C ID 65**			**C ID 1**	**C ID 56**	**C ID 65**			
15	0.57	0.60	0.50			0.28	0.42	0.30			**5.06**
16	0.60	0.63	0.59			0.28	0.42	0.30			**5.11**
17	0.63	0.63	0.65			0.28	0.42	0.30			**1.03**
	C ID 1	**C ID 46**	**C ID 60**			**C ID 1**	**C ID 46**	**C ID 60**			
19	0.60	0.57	0.53			0.28	0.41	0.31			**2.03**
20	0.55	0.56	0.63			0.28	0.41	0.31			**4.06**
21	0.63	0.66	0.63			0.28	0.41	0.31			**4.11**
	C ID 42	**C ID 57**	**C ID 65**			**C ID 42**	**C ID 57**	**C ID 65**			
22	0.60	0.63	0.62			0.34	0.38	0.28			**5.12**
23	0.65	0.59	0.62			0.34	0.38	0.28			**5.12**
24	0.60	0.56	0.63			0.34	0.38	0.28			**1.02**
	C ID 42	**C ID 48**	**C ID 57**			**C ID 42**	**C ID 48**	**C ID 57**			
26	0.63	0.60	0.63			0.23	0.37	0.40			**2.05**
27	0.65	0.60	0.60			0.23	0.37	0.40			**4.09**
28	0.63	0.62	0.56			0.23	0.37	0.40			**4.08**
	C ID 2	**C ID 5**	**C ID 56**			**C ID 2**	**C ID 5**	**C ID 56**			
29	0.60	0.62	0.63			0.37	0.22	0.41			**5.12**
30	0.57	0.63	0.60			0.37	0.22	0.41			**5.10**
31	0.62	0.65	0.62			0.37	0.22	0.41			**1.03**
	C ID 45	**C ID 51**	**C ID 61**	**C ID 65**		**C ID 45**	**C ID 51**	**C ID 61**	**C ID65**		
33	0.62	0.63	0.66	0.66		0.32	0.26	0.22	0.20		**2.06**
34	0.66	0.65	0.63	0.64		0.32	0.26	0.22	0.20		**4.12**
35	0.62	0.60	0.63	0.65		0.32	0.26	0.22	0.20		**4.10**
	C ID 5	**C ID 36**	**C ID 53**			**C ID 5**	**C ID 36**	**C ID 53**			
36	0.60	0.63	0.65			0.26	0.37	0.37			**5.13**
37	0.66	0.63	0.64			0.26	0.37	0.37			**5.14**
38	0.63	0.63	0.66			0.26	0.37	0.37			**1.03**
	C ID 40	**C ID 47**	**C ID 55**	**C ID 58**		**C ID 40**	**C ID 47**	**C ID 55**	**C ID58**		
40	0.63	0.63	0.65	0.65		0.26	0.24	0.22	0.28		**2.06**
41	0.66	0.65	0.60	0.63		0.26	0.24	0.22	0.28		**4.11**
42	0.64	0.65	0.65	0.66		0.26	0.24	0.22	0.28		**4.12**
	C ID 2	**C ID 51**	**C ID 65**			**C ID 2**	**C ID 51**	**C ID 65**			
43	0.63	0.62	0.66			0.37	0.35	0.28			**5.14**
44	0.63	0.62	0.64			0.37	0.35	0.28			**5.13**
45	0.65	0.64	0.66			0.37	0.35	0.28			**1.03**
	C ID 1	**C ID 42**	**C ID 48**			**C ID 1**	**C ID 42**	**C ID 48**			
47	0.60	0.66	0.64			0.28	0.36	0.36			**2.05**
48	0.65	0.62	0.60			0.28	0.36	0.36			**4.10**
49	0.65	0.65	0.64			0.28	0.36	0.36			**4.12**
	C ID 1	**C ID 2**	**C ID 3**	**C ID 5**	**C ID 45**	**C ID 1**	**C ID 2**	**C ID 3**	**C ID 5**	**C ID 45**	
50	0.63	0.61	0.63	0.64	0.60	0.18	0.24	0.16	0.14	0.28	**5.12**
51	0.62	0.64	0.64	0.62	0.66	0.18	0.24	0.16	0.14	0.28	**5.14**
52	0.56	0.60	0.64	0.65	0.63	0.18	0.24	0.16	0.14	0.28	**1.02**
	C ID 42	**C ID 57**	**C ID 60**			**C ID 42**	**C ID 57**	**C ID 60**			
70	0.63	0.65	0.65			0.34	0.37	0.29			**14.43**
	C ID 2	**C ID 41**	**C ID 46**			**C ID 2**	**C ID 41**	**C ID 46**			
122	0.60	0.62	0.61			0.31	0.34	0.35			**20.43**
124	0.63	0.64	0.62			0.31	0.34	0.35			**20.52**
126	0.63	0.66	0.63			0.31	0.34	0.35			**20.56**
128	0.56	0.62	0.60			0.31	0.34	0.35			**20.38**
130	0.60	0.63	0.66			0.31	0.34	0.35			**20.53**
132	0.64	0.65	0.66			0.31	0.34	0.35			**20.59**
134	0.65	0.63	0.62			0.31	0.34	0.35			**20.53**
136	0.63	0.66	0.66			0.31	0.34	0.35			**20.60**
	C ID 42	**C ID 57**	**C ID 60**	**C ID 65**		**C ID 42**	**C ID 57**	**C ID 60**	**C ID 65**		
139	0.60	0.61	0.60	0.63		0.26	0.30	0.22	0.22		**20.44**
141	0.62	0.63	0.65	0.61		0.26	0.30	0.22	0.22		**20.50**
143	0.66	0.65	0.64	0.63		0.26	0.30	0.22	0.22		**20.58**
145	0.64	0.63	0.65	0.65		0.26	0.30	0.22	0.22		**20.57**
147	0.63	0.66	0.65	0.66		0.26	0.30	0.22	0.22		**20.60**
149	0.66	0.65	0.66	0.65		0.26	0.30	0.22	0.22		**20.62**
151	0.64	0.65	0.63	0.64		0.26	0.30	0.22	0.22		**20.57**
153	0.65	0.62	0.60	0.65		0.26	0.30	0.22	0.22		**20.52**

Appendix-F2: Table showing duration of each critical activity of case study-2

Activity No	Random 1	Random 2	Random 3	Random 4	Random 5	Random 6	Rand 1 RF 1	Rand 2 RF 2	Rand 3 RF 3	Rand 4 RF 4	Rand 5 RF 5	Rand 6 RF 6	Duration of activity
	C ID 8	**C ID 43**	**C ID 64**	**C ID 69**			**C ID 8**	**C ID 43**	**C ID 64**	**C ID 69**			
2	0.62	0.66	0.60	0.66			0.16	0.31	0.25	0.29			**2.57**
	C ID 8	**C ID 10**	**C ID 60**				**C ID 8**	**C ID 10**	**C ID 60**				
4	0.58	0.62	0.61				0.24	0.4	0.36				**4.45**
5	0.59	0.57	0.56				0.24	0.4	0.36				**5.36**
6	0.63	0.60	0.56				0.24	0.4	0.36				**15.57**
	C ID 1	**C ID 10**	**C ID 13**	**C ID 57**	**C ID 65**		**C ID 1**	**C ID 10**	**C ID 13**	**C ID 57**	**C ID 65**		
7	0.63	0.62	0.62	0.60	0.66		0.18	0.22	0.15	0.26	0.19		**13.13**
8	0.58	0.56	0.60	0.63	0.62		0.18	0.22	0.15	0.26	0.19		**9.24**
9	0.59	0.59	0.63	0.60	0.63		0.18	0.22	0.15	0.26	0.19		**13.10**
10	0.61	0.58	0.57	0.62	0.64		0.18	0.22	0.15	0.26	0.19		**9.25**
	C ID 2	**C ID 51**	**C ID 53**	**C ID 61**			**C ID 2**	**C ID 51**	**C ID 53**	**C ID 61**			
12	0.63	0.63	0.58	0.65			0.28	0.26	0.23	0.23			**15.69**
13	0.60	0.59	0.55	0.60			0.28	0.26	0.23	0.23			**33.40**
	C ID 1	**C ID 10**	**C ID 42**	**C ID 57**	**C ID 65**		**C ID 1**	**C ID 10**	**C ID 42**	**C ID 57**	**C ID 65**		
21	0.59	0.60	0.56	0.55	0.60		0.17	0.2	0.22	0.24	0.17		**13.99**
22	0.60	0.63	0.57	0.56	0.61		0.17	0.2	0.22	0.24	0.17		**30.55**
30	0.58	0.62	0.59	0.60	0.61		0.17	0.2	0.22	0.24	0.17		**14.04**
31	0.57	0.62	0.63	0.63	0.63		0.17	0.2	0.22	0.24	0.17		**30.70**
39	0.60	0.63	0.66	0.63	0.60		0.17	0.2	0.22	0.24	0.17		**14.11**
40	0.61	0.62	0.60	0.57	0.62		0.17	0.2	0.22	0.24	0.17		**30.60**
	C ID 2	**C ID 4**	**C ID 10**	**C ID 57**			**C ID 2**	**C ID 4**	**C ID 10**	**C ID 57**			
48	0.62	0.58	0.63	0.65	0.64		0.28	0.17	0.25	0.3			**7.36**
49	0.60	0.58	0.62	0.55	0.57		0.28	0.17	0.25	0.3			**7.30**
	C ID 1	**C ID 10**	**C ID 42**	**C ID 48**	**C ID 57**	**C ID 65**	**C ID 1**	**C ID 10**	**C ID 42**	**C ID 48**	**C ID 57**	**C ID 65**	
52	0.63	0.65	0.61	0.63	0.58	0.66	0.14	0.16	0.18	0.2	0.18	0.14	**17.61**
53	0.62	0.60	0.58	0.63	0.58	0.64	0.14	0.16	0.18	0.2	0.18	0.14	**15.13**
	C ID 1	**C ID 2**	**C ID 10**	**C ID 45**	**C ID 64**		**C ID 1**	**C ID 2**	**C ID 10**	**C ID 45**	**C ID 64**		
54	0.66	0.64	0.63	0.63	0.65		0.16	0.21	0.19	0.25	0.19		**31.81**
59	0.62	0.55	0.60	0.58	0.58		0.16	0.21	0.19	0.25	0.19		**21.30**
	C ID 2	**C ID 41**	**C ID 42**	**C ID 46**	**C ID 48**	**C ID 65**	**C ID 2**	**C ID 41**	**C ID 42**	**C ID 46**	**C ID 48**	**C ID 65**	
61	0.62	0.65	0.58	0.58	0.63	0.61	0.17	0.18	0.16	0.19	0.17	0.13	**5.42**
62	0.60	0.57	0.60	0.60	0.58	0.60	0.17	0.18	0.16	0.19	0.17	0.13	**2.51**
	C ID 45	**C ID 50**	**C ID 56**				**C ID 45**	**C ID 50**	**C ID 56**				
63	0.63	0.65	0.66				0.34	0.34	0.32				**8.37**

Appendix-G:

List of figures showing user's Interface of delay analysis system

This appendix includes the list of different figures of user's interface that shows different functionality of the delay analyses system developed during the course of study. A total of 10 figures included in the representing different command for demonstrating the delay analysis system and presentation of results. The interfaces of main form included seven commands for different purposes. The details of each command are discussed in chapter 6. The first command of the system is the information register command (see figure 1). This command is used to store the user information in database, which is considered as excel sheet.

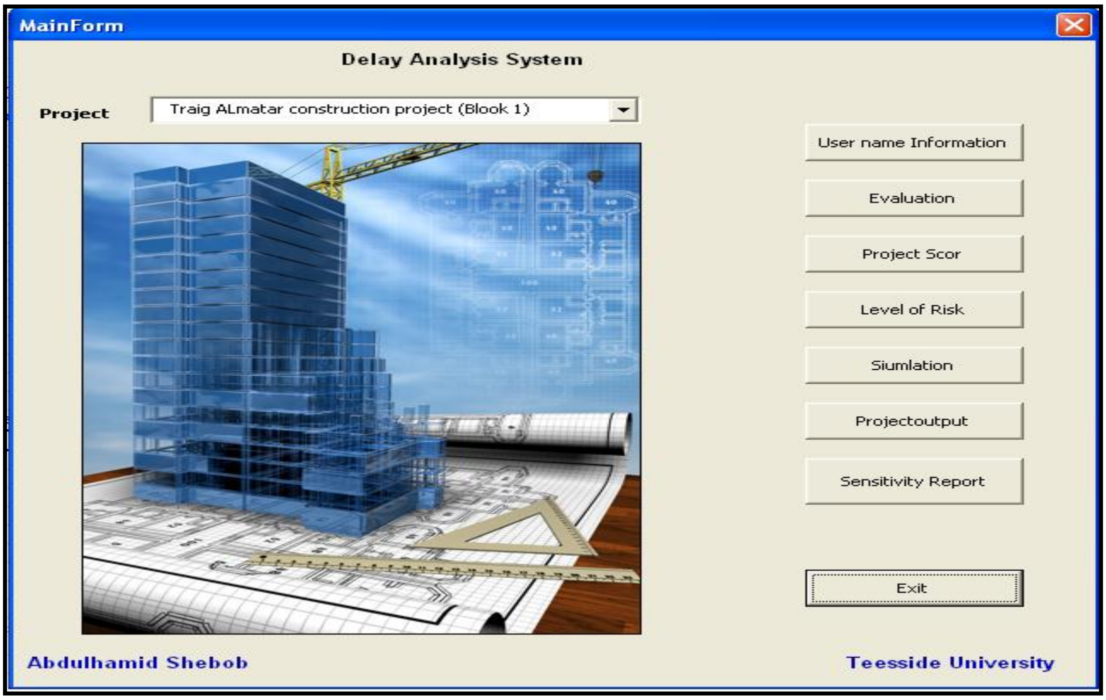


Figure 1: User's Interface of the simulation model of delay analysis system

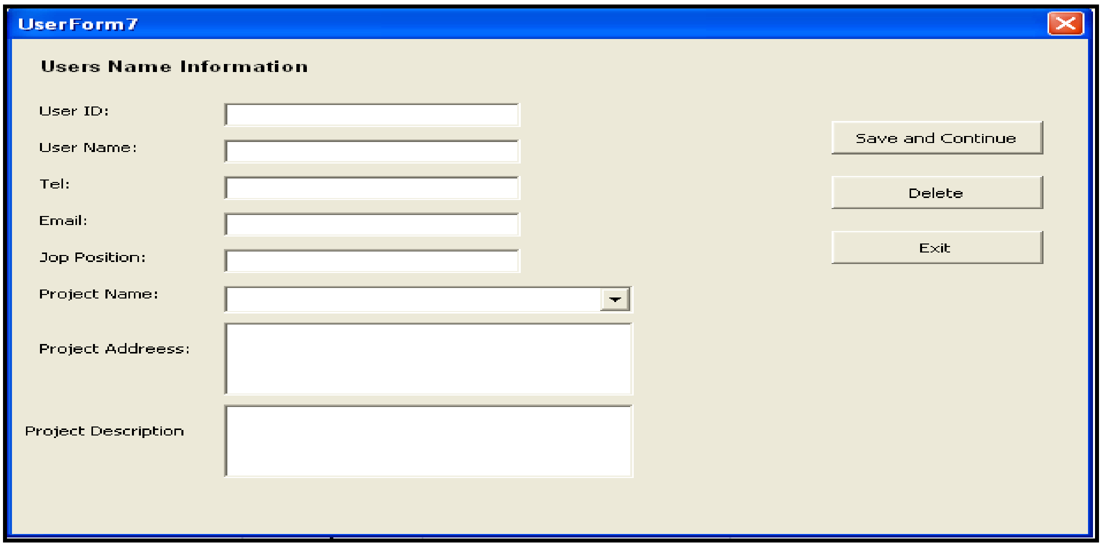
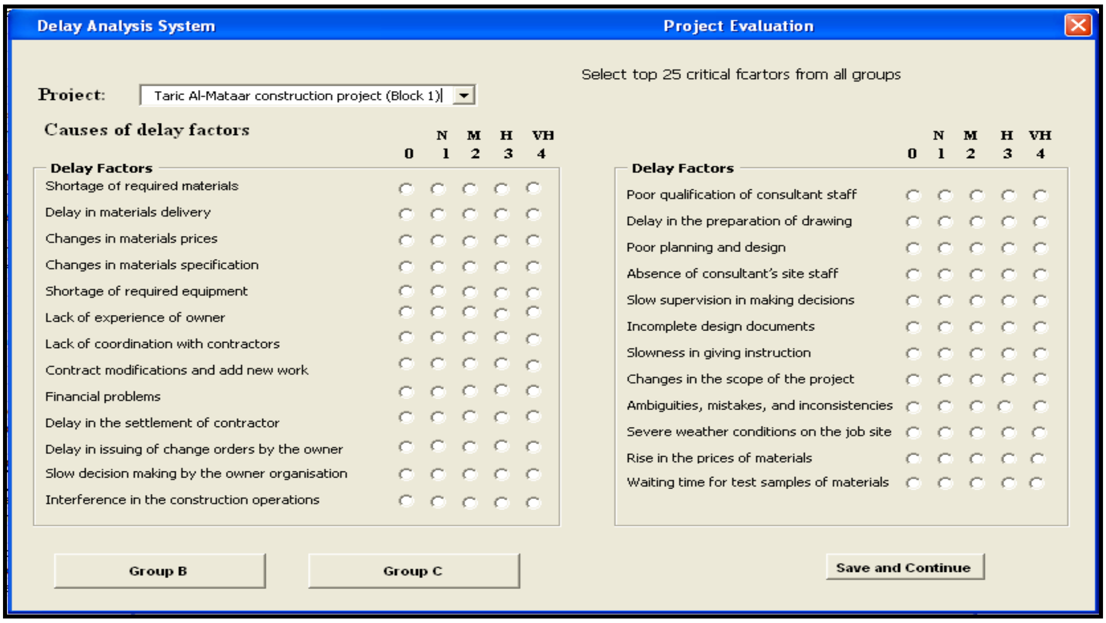
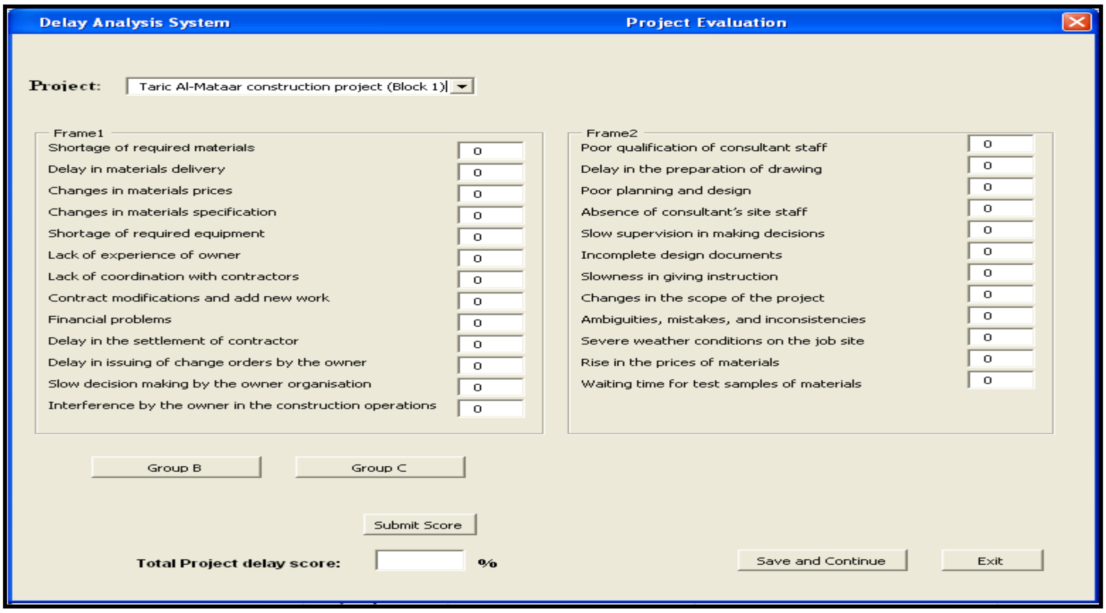


Figure 2 show the snapshot of user's information input form

The evaluation system summarised the scores of each delay factors and provided the total score of risk level using a form shown in figure 3 below



Figures 3: Input form of score that are identified by project team members



Figures 4: showing form of calculating total project score of the system

Figure 5: shown the report of risk evaluation based on calculated score in figure 4

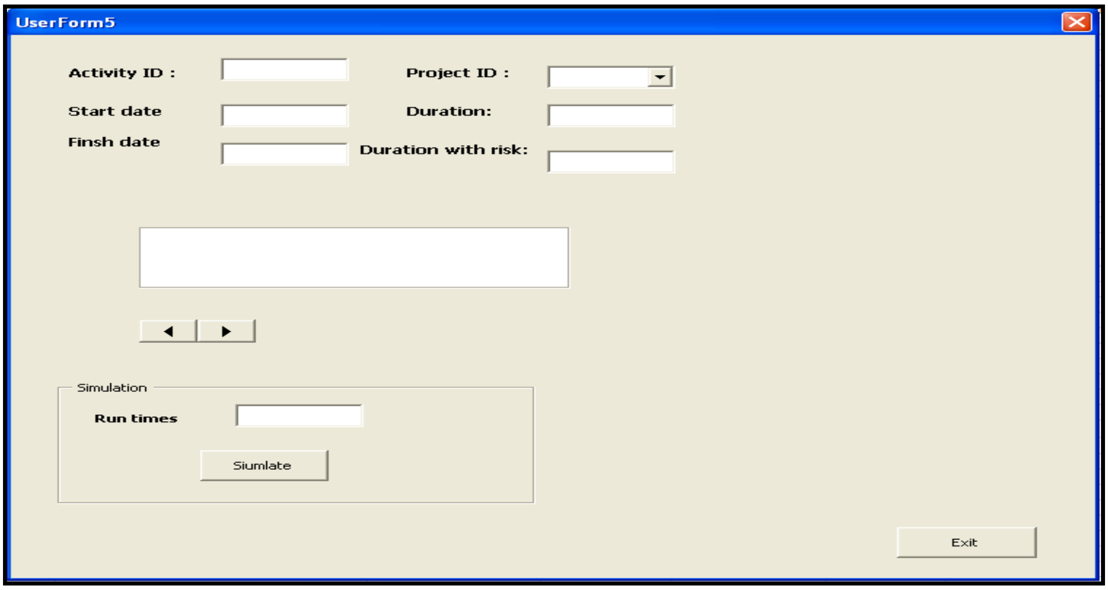


Figure 6: typical form for displaying activity information

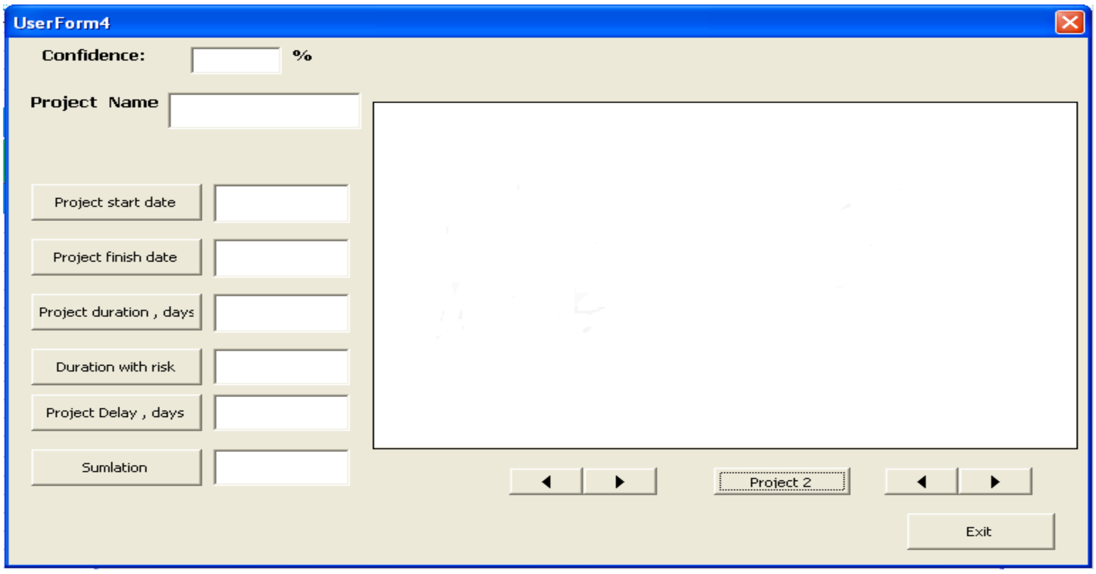


Figure 7: typical form for displaying simulation results of a project

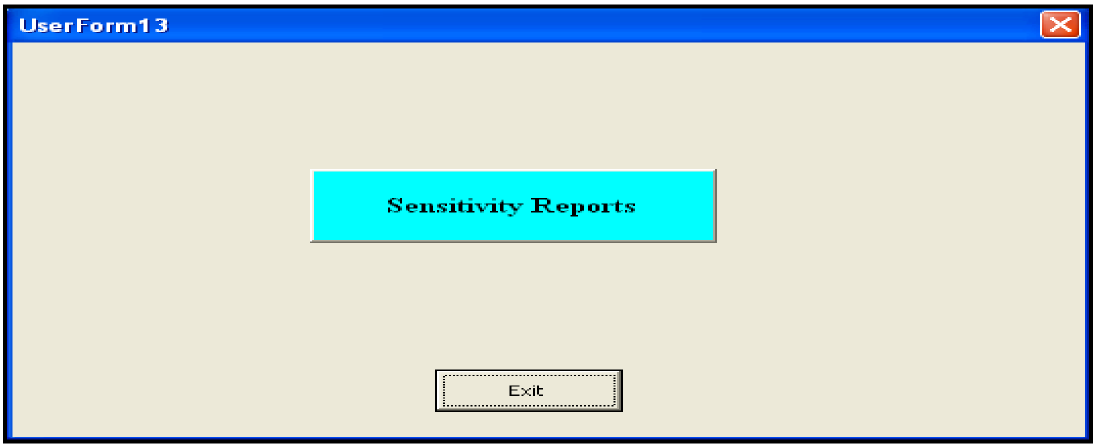
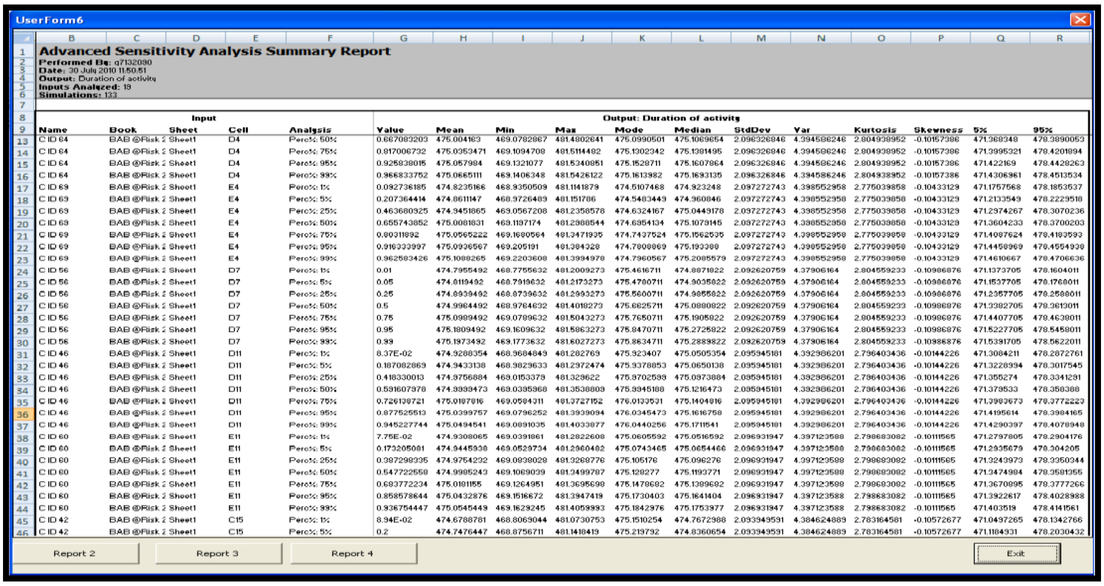


Figure 8 command form for generating the sensitivity report



Advanced Sensitivity Analysis Summary Report
Performed By: q7132090
Date: 30 July 2010 11:50:51
Output: Duration of activity
Inputs Analyzed: 18
Simulations: 133

Input					Output: Duration of activity											
Name	Book	Sheet	Cell	Analysis	Value	Mean	Min	Max	Mode	Median	StdDev	Var	Kurtosis	Skewness	5%	95%
C ID 64	BAB @Risk 2	Sheet1	D4	Perc%: 50%	0.667083203	475.004163	469.0782867	481.4802641	475.0990501	475.1069654	2.096326846	4.394586246	2.804938952	-0.10157386	471.368348	478.3890053
C ID 64	BAB @Risk 2	Sheet1	D4	Perc%: 75%	0.817006732	475.0353471	469.1094708	481.5114482	475.1302342	475.1381495	2.096326846	4.394586246	2.804938952	-0.10157386	471.3995321	478.4201894
C ID 64	BAB @Risk 2	Sheet1	D4	Perc%: 95%	0.925838015	475.057984	469.1321077	481.5340851	475.1528711	475.1607864	2.096326846	4.394586246	2.804938952	-0.10157386	471.422169	478.4428263
C ID 64	BAB @Risk 2	Sheet1	D4	Perc%: 99%	0.966833752	475.0665111	469.1406348	481.5426122	475.1613982	475.1693135	2.096326846	4.394586246	2.804938952	-0.10157386	471.4306961	478.4513534
C ID 69	BAB @Risk 2	Sheet1	E4	Perc%: 1%	0.092736185	474.8235166	468.9350509	481.1141879	474.5107468	474.923248	2.097272743	4.398552958	2.775039858	-0.10433129	471.1757568	478.1853537
C ID 69	BAB @Risk 2	Sheet1	E4	Perc%: 5%	0.207364414	474.8611147	468.9726489	481.151786	474.5483449	474.960846	2.097272743	4.398552958	2.775039858	-0.10433129	471.2133549	478.2229518
C ID 69	BAB @Risk 2	Sheet1	E4	Perc%: 25%	0.463680925	474.9451865	469.0567208	481.2358578	474.6324167	475.0449178	2.097272743	4.398552958	2.775039858	-0.10433129	471.2974267	478.3070236
C ID 69	BAB @Risk 2	Sheet1	E4	Perc%: 50%	0.655743852	475.0081831	469.1197174	481.2988544	474.6954134	475.1079145	2.097272743	4.398552958	2.775039858	-0.10433129	471.3604233	478.3700203
C ID 69	BAB @Risk 2	Sheet1	E4	Perc%: 75%	0.80311892	475.0565222	469.1680564	481.3471935	474.7437524	475.1562535	2.097272743	4.398552958	2.775039858	-0.10433129	471.4087624	478.4183593
C ID 69	BAB @Risk 2	Sheet1	E4	Perc%: 95%	0.916333997	475.0936567	469.205191	481.384328	474.7808869	475.193388	2.097272743	4.398552958	2.775039858	-0.10433129	471.4458969	478.4554938
C ID 69	BAB @Risk 2	Sheet1	E4	Perc%: 99%	0.962583426	475.1088265	469.2203608	481.3994978	474.7960567	475.2085579	2.097272743	4.398552958	2.775039858	-0.10433129	471.4610667	478.4706636
C ID 56	BAB @Risk 2	Sheet1	D7	Perc%: 1%	0.01	474.7955492	468.7755632	481.2009273	475.4616711	474.8871822	2.092620759	4.37906164	2.804559233	-0.10986876	471.1373705	478.1604011
C ID 56	BAB @Risk 2	Sheet1	D7	Perc%: 5%	0.05	474.8119492	468.7919632	481.2173273	475.4780711	474.9035822	2.092620759	4.37906164	2.804559233	-0.10986876	471.1537705	478.1768011
C ID 56	BAB @Risk 2	Sheet1	D7	Perc%: 25%	0.25	474.8939492	468.8739632	481.2993273	475.5600711	474.9855822	2.092620759	4.37906164	2.804559233	-0.10986876	471.2357705	478.2588011
C ID 56	BAB @Risk 2	Sheet1	D7	Perc%: 50%	0.5	474.9964492	468.9764632	481.4018273	475.6625711	475.0880822	2.092620759	4.37906164	2.804559233	-0.10986876	471.3382705	478.3613011
C ID 56	BAB @Risk 2	Sheet1	D7	Perc%: 75%	0.75	475.0989492	469.0789632	481.5043273	475.7650711	475.1905822	2.092620759	4.37906164	2.804559233	-0.10986876	471.4407705	478.4638011
C ID 56	BAB @Risk 2	Sheet1	D7	Perc%: 95%	0.95	475.1809492	469.1609632	481.5863273	475.8470711	475.2725822	2.092620759	4.37906164	2.804559233	-0.10986876	471.5227705	478.5458011
C ID 56	BAB @Risk 2	Sheet1	D7	Perc%: 99%	0.99	475.1973492	469.1773632	481.6027273	475.8634711	475.2889822	2.092620759	4.37906164	2.804559233	-0.10986876	471.5391705	478.5622011
C ID 46	BAB @Risk 2	Sheet1	D11	Perc%: 1%	8.37E-02	474.9288354	468.9684849	481.282769	475.923407	475.0505354	2.095945181	4.392986201	2.796403436	-0.10144226	471.3084211	478.2872761
C ID 46	BAB @Risk 2	Sheet1	D11	Perc%: 5%	0.187082869	474.9433138	468.9829633	481.2972474	475.9378853	475.0650138	2.095945181	4.392986201	2.796403436	-0.10144226	471.3228994	478.3017545
C ID 46	BAB @Risk 2	Sheet1	D11	Perc%: 25%	0.418330013	474.9756884	469.0153379	481.329622	475.9702599	475.0973884	2.095945181	4.392986201	2.796403436	-0.10144226	471.355274	478.3341291
C ID 46	BAB @Risk 2	Sheet1	D11	Perc%: 50%	0.591607978	474.9999473	469.0395968	481.3538809	475.9945188	475.1216473	2.095945181	4.392986201	2.796403436	-0.10144226	471.379533	478.358388
C ID 46	BAB @Risk 2	Sheet1	D11	Perc%: 75%	0.726138721	475.0187816	469.0584311	481.3727152	476.0133531	475.1404816	2.095945181	4.392986201	2.796403436	-0.10144226	471.3983673	478.3772223
C ID 46	BAB @Risk 2	Sheet1	D11	Perc%: 95%	0.877525513	475.0399757	469.0796252	481.3939094	476.0345473	475.1616758	2.095945181	4.392986201	2.796403436	-0.10144226	471.4195614	478.3984165
C ID 46	BAB @Risk 2	Sheet1	D11	Perc%: 99%	0.945227744	475.0494541	469.0891035	481.4033877	476.0440256	475.1711541	2.095945181	4.392986201	2.796403436	-0.10144226	471.4290397	478.4078948
C ID 60	BAB @Risk 2	Sheet1	E11	Perc%: 1%	7.75E-02	474.9308065	469.0391861	481.2822608	475.0605592	475.0516592	2.096931947	4.397123588	2.798683082	-0.10111565	471.2797805	478.2904176
C ID 60	BAB @Risk 2	Sheet1	E11	Perc%: 5%	0.173205081	474.9445938	469.0529734	481.2960482	475.0743465	475.0654466	2.096931947	4.397123588	2.798683082	-0.10111565	471.2935679	478.304205
C ID 60	BAB @Risk 2	Sheet1	E11	Perc%: 25%	0.387298335	474.9754232	469.0838028	481.3268776	475.105176	475.096276	2.096931947	4.397123588	2.798683082	-0.10111565	471.3243973	478.3350344
C ID 60	BAB @Risk 2	Sheet1	E11	Perc%: 50%	0.547722558	474.9985243	469.1069039	481.3499787	475.128277	475.1193771	2.096931947	4.397123588	2.798683082	-0.10111565	471.3474984	478.3581355
C ID 60	BAB @Risk 2	Sheet1	E11	Perc%: 75%	0.683772234	475.0181155	469.1264951	481.3695698	475.1478682	475.1389682	2.096931947	4.397123588	2.798683082	-0.10111565	471.3670895	478.3777266
C ID 60	BAB @Risk 2	Sheet1	E11	Perc%: 95%	0.858578644	475.0432876	469.1516672	481.3947419	475.1730403	475.1641404	2.096931947	4.397123588	2.798683082	-0.10111565	471.3922617	478.4028988
C ID 60	BAB @Risk 2	Sheet1	E11	Perc%: 99%	0.936754447	475.0545449	469.1629245	481.4059993	475.1842976	475.1753977	2.096931947	4.397123588	2.798683082	-0.10111565	471.403519	478.4141561
C ID 42	BAB @Risk 2	Sheet1	C15	Perc%: 1%	8.94E-02	474.6788781	468.8069044	481.0730753	475.1510254	474.7672988	2.093949591	4.384624889	2.783164581	-0.10572677	471.0497265	478.1342766
C ID 42	BAB @Risk 2	Sheet1	C15	Perc%: 5%	0.2	474.7476447	468.8756711	481.1418419	475.219792	474.8360654	2.093949591	4.384624889	2.783164581	-0.10572677	471.1184931	478.2030432

Figure 9 snapshot of sensitivity report presented in tabular form.

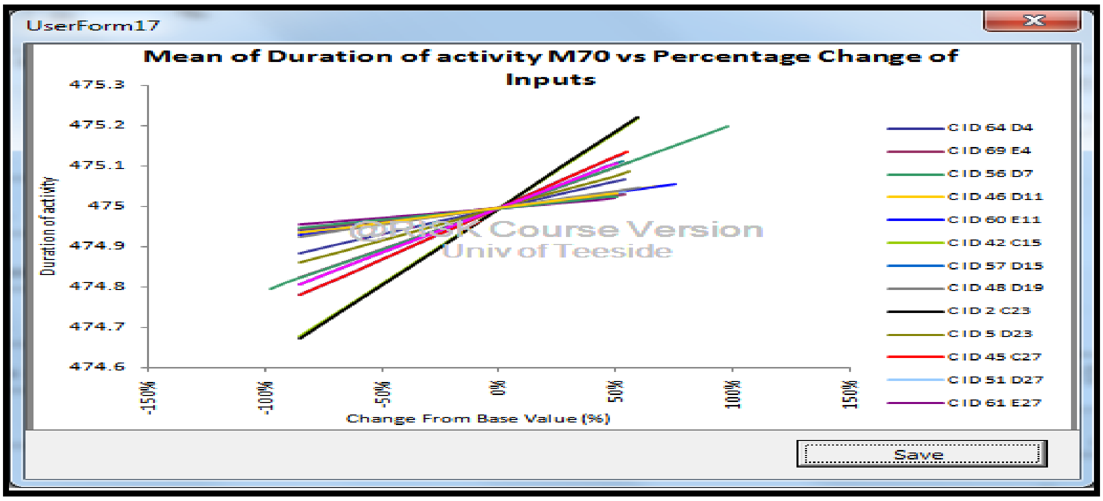


Figure 10 snapshot of sensitivity report presented in graphical format

Appendix-I

Snapshots of Site visits in Libya

The appendix-I includes a couple of snapshots of building construction sites in Libya, which were observed during the construction industry survey. It was found that that cement, steel, sand, hollow blocks, glass, wood and water are the most important construction materials used in Libyan building projects. Among the major construction materials, Cement, glass, steel and other MEP (mechanical, electrical, plumbing) materials were imported from international markets due to unavailability in local market.

Figure -1: Materials storage at construction site

Figure -2: Precast yard of Cement-based construction material (Cement bricks)

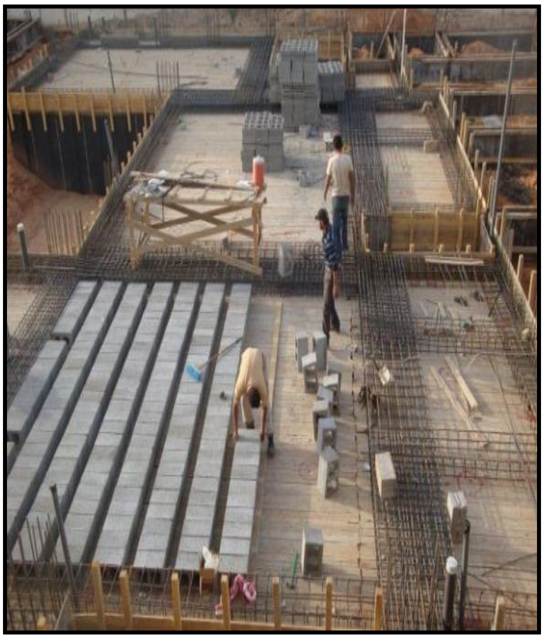


Figure -3: Placing hollow boxes before concreting the slab of the building in Taric Al-Mataar construction projects in Tripoli city

Figure -4: rebar fixing in second floor of the building at Taric Al-Mataar construction site in Tripoli city

Figure -5: snapshot of rebar fixing at construction site of block-2 building at Taric Al-Mataar construction project in Tripoli.

Figure -6: snapshot of site visit with consultant engineer of a construction project at Ras Igdir.

Figure -7: snapshot of idle tower crane waiting for materials at a construction project in Tripoli city

Figure -8: snapshot of dismantling side works due to design error at construction site of Customs port in Ras Igdir.

Figure -9: snapshot of manual concreting operation at a building project in Beny-wallid city.

Figure -10: snapshot of ready mix concrete plant at Taric Al-Mataar in Tripoli.

Appendix-H:

List of publications

Journal Papers

1. Shebob. A; Dawood. N; Shah. R (2012) “Development of a methodology for analysing and quantifying the impact of delay factors affecting construction projects” at Journal of Construction Engineering and Project Management (Publication).

2. Shebob. A; Dawood. N; Shah. R; Xu. Q (2011) “A Comparative study of delay factors in Libyan and UK Construction Industry”, Journal Paper, at Engineering, Construction and Architectural Management. (Publication).

International Conference Papers

1. Shebob. A; Dawood. N; Xu. Q, (2010) a comparative study and delays factors in Libya and the United Kingdom construction industry. The Participations for the third scientific research Symposium. For the Libyan Student at Sheffield Hallam University in the UK 18- May -2010.

2. Shebob. A; Dawood. N; Xu. Q, (2010) A comparative study and risk modelling of delays factors in Libya and the United Kingdom construction industry (Libyan Engineering Society, University of Nottingham UK 12- July - 2010)

3. Shebob. A; Dawood. N; Xu. Q (2011) A comparative study of delays factors in project completion in Libya and UK construction industry (the 4th International Conference on Construction Engineering and Project Management, School of Civil and Environmental Engineering & Faculty of Built Environment, University of New South Wales, Sydney, Australia 16-18-Feb- 2011.

4. Shebob. A; Dawood. N (2011) Analysing construction delays factors: A case study of building construction in Libya (27th Annual Conference and Annual

General Meeting University of the West of England, Bristol, UK 5th – Wed 7th September 2011.